Juvenile Salmonid Monitoring in Battle Creek, California, October 2004 through September 2005

USFWS Report
Prepared by:

Kellie S. Whitton
Jess M. Newton
Matthew R. Brown

U.S. Fish and Wildlife Service
Red Bluff Fish and Wildlife Office
10950 Tyler Road
Red Bluff, CA 96080

June 2007

Disclaimer

The suggested citation for this report is:
Whitton, K. S., J. M. Newton, and M. R. Brown. 2007. Juvenile salmonid monitoring in Battle Creek, California, October 2004 through September 2005. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Juvenile Salmonid Monitoring in Battle Creek, California, October 2004 through September 2005

Kellie S. Whitton, Jess M. Newton, and Matthew R. Brown

U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office
10959 Tyler Road, Red Bluff, CA 96080, (530)527-3043

Abstract- In October 2004, the U.S. Fish and Wildlife Service continued an ongoing juvenile salmonid monitoring project on Battle Creek, California, using rotary screw traps. Battle Creek, a tributary of the Sacramento River, is important to the conservation and recovery of federally listed anadromous salmonids in the Sacramento River watershed because of its unique hydrology, geology, and habitat suitability for several anadromous species. Information about juvenile salmonid abundance and migration in Battle Creek is necessary to guide efforts at maintaining and eventually restoring populations of threatened and endangered anadromous salmonids. From October 2004 through September 2005 four runs of Chinook salmon *Oncorhynchus tshawytscha*, rainbow trout/steelhead *Oncorhynchus mykiss*, and 13 species of non-salmonids were captured in either the Lower (LBC) or Upper Battle Creek (UBC) rotary screw traps. To determine rotary screw-trap efficiency, we conducted 28 and 30 mark-recapture trials at the LBC and UBC traps, respectively during January 4 through May 13, 2005. Full and half-cone trap efficiencies ranged from 2.2 to 10.1% at LBC and 2.3 to 8.9 % at UBC. Chinook salmon run designations were made using length-at-date criteria developed for the Sacramento River, which likely resulted in underestimates of spring and late-fall and overestimates of fall Chinook salmon production at both traps. The brood year 2004 spring and fall Chinook salmon passage estimates at the LBC trap were 7,983 and 4,349,127 respectively. The brood year 2005 late-fall Chinook salmon passage estimate at the LBC trap was 69,169. The annual passage of winter Chinook salmon was not estimated for the lower trap because they were likely using Battle Creek for non-natal rearing (N=445). The passage estimate for age 1+ rainbow trout/steelhead at the LBC trap was 357 and 3,422 for brood year 2005 young-of-the-year. Brood year 2004 spring Chinook salmon passage at the UBC trap was 3,253. The brood year 2004 fall Chinook salmon passage estimate at the upper trap was 26,763. The brood year 2005 late-fall Chinook salmon passage estimate at the UBC trap was 147. Passage estimates were not made for winter Chinook salmon at the upper trap as catch rates (N=4) were too low. The passage estimate for age 1+ rainbow trout/steelhead at the upper trap was 485 and 5,490 for brood year 2005 young-of-the-year.

Table of Contents

List of Tables

List of Figures

Introduction

In recent decades, California has experienced declines in several of its wild salmon and steelhead populations. These declines have been linked to a variety of factors, but the development of federal, state, municipal, and private water projects is likely a primary contributing factor (Jones and Stokes 2005). As a result of the declines, two populations of Chinook salmon (*Oncorhynchus tshawytscha*) and one population of steelhead (*O. mykiss*) in the Sacramento River watershed have been listed as threatened or endangered under the Endangered Species Act (ESA) or the California Endangered Species Act (CESA).

Battle Creek, a tributary of the Sacramento River, is important to the conservation and recovery of federally listed anadromous salmonids in the Sacramento River watershed because of its unique hydrology, geology, and habitat suitability for several anadromous species and historical land uses (Jones and Stokes 2005). Restoration actions and projects that are planned or have begun in Battle Creek focus on providing habitat for the endangered Sacramento River winter Chinook salmon, the threatened Central Valley spring Chinook salmon, and the threatened Central Valley steelhead. Currently the geographic range of the winter Chinook salmon Evolutionary Significant Unit is small and limited to the mainstem of the Sacramento River between Keswick Dam and the town of Red Bluff, California, where it may be susceptible to catastrophic loss. Establishing a second population in Battle Creek could reduce the likelihood of extinction. Battle Creek also has the potential to support significant, self-sustaining populations of spring Chinook salmon and steelhead.

Since the early 1900's, a hydroelectric project comprised of several dams, canals, and powerhouses has operated in the Battle Creek watershed. The hydroelectric project, which is currently owned by Pacific Gas and Electric Company (PG&E), has had severe impacts upon anadromous salmonids and their habitat (Ward and Kier 1999), including a reduction of instream flows, barriers to migration, loss of habitat, flow related temperature impacts, etc.

In 1992, the Central Valley Project Improvement Act (CVPIA), federally legislated efforts to double populations of Central Valley anadromous salmonids. The CVPIA Anadromous Fisheries Restoration Program outlined actions to restore Battle Creek, which included increasing flows past PG&E's hydroelectric power diversions to provide adequate holding, spawning, and rearing habitat for anadromous salmonids (USFWS 1997). Prior to 2001, PG&E was required under its Federal Energy Regulatory Commission (FERC) license to provide minimum instream flows of 0.08 m^3/s (3 cfs) downstream of diversions on North Fork Battle Creek and 0.14 m^3/s (5 cfs) downstream of diversions on South Fork Battle Creek. However, from 1995 to 2001, the CVPIA Water Acquisition Program contracted with PG&E to increase minimum stream flow in the lower reaches of the north and south forks of Battle Creek. This initial flow augmentation provided flows between 0.71 and 0.99 m^3/s (25 and 35 cfs) below Eagle Canyon Dam on the north fork and below Coleman Diversion Dam on the south fork.

In 1999, PG&E, California Department of Fish and Game (CDFG), U.S. Fish and Wildlife Service (USFWS), U.S. Bureau of Reclamation (USBR), and National Marine Fisheries Service (NMFS) signed a Memorandum of Understanding (MOU) to formalize the agreement regarding the Battle Creek Chinook Salmon and Steelhead Restoration Project (Restoration Project). The planning, designing, and permitting phases of the Restoration Project have taken longer than originally anticipated; therefore, funds for increased minimum flows in North and South Fork Battle Creek from the CVPIA Water Acquisition Program ran out in 2001. However, the federal and State of California interagency program known as the CALFED Bay-Delta Program (CALFED) funded the Battle Creek Interim Flow Project beginning in 2001 and will continue to until the Restoration Project begins. The intent of the Interim Flow Project (IFP) is to provide immediate habitat improvement in the lower reaches of Battle Creek to sustain current natural populations while implementation of the more comprehensive Restoration Project moves forward. Under the IFP, PG&E would maintain minimum instream flows at 0.85 m^3/s (30 cfs) by reducing their hydroelectric power diversions from May to October. In 2001, funding for the IFP was provided for the north fork, but not the south fork. In 2002, some of the north fork IFP flows were reallocated to the south fork under an agreement which allows for changing flows on either of the forks based on environmental conditions (i.e., water temperatures, numbers and locations of live Chinook salmon and redds). Beginning in late 2002, the IFP began providing the full minimum flow of 0.85 m^3/s (30 cfs) on both forks. In 2001, increased flows were provided only on the north fork in part based on observations of higher Chinook salmon spawning on the north fork than on the south fork. Redd counts from 1995 to 1998 indicated that 39% of spawning occurred in the north fork versus 23% in the south fork (RBFWO, unpublished data).

The U.S. Fish and Wildlife Services' Red Bluff Fish and Wildlife Office began using rotary screw traps to monitor juvenile salmonids on Battle Creek, Shasta and Tehama Counties, California, in September 1998 (Whitton et al. 2006). The purpose of this report is to summarize data collected during the period October 1, 2004 through September 30, 2005. This ongoing monitoring project has three primary objectives: (1) determine an annual juvenile passage index (JPI) for Chinook salmon (salmon) and rainbow trout/steelhead (trout), for inter-year comparisons; (2) obtain juvenile salmonid life history information including size, condition, emergence, emigration timing, and potential factors limiting survival at various life stages, and (3) collect tissue samples for genetic analyses.

Study Area

Battle Creek and its tributaries drain the western volcanic slopes of Mount Lassen in the southern Cascade Range. The creek has two primary tributaries, North Fork Battle Creek which originates near Mt. Huckleberry and South Fork Battle Creek which originates in Battle Creek Meadows south of the town of Mineral, California. North Fork Battle Creek is approximately 47.5 km (29.5 miles) long from the headwaters to the confluence and has a natural barrier waterfall located 21.7 km (rm 13.5) from the confluence (Jones and Stokes 2004). South Fork Battle Creek is approximately 45 km (28 miles) long and has a natural barrier waterfall (Angel Falls) located 30.4 km (rm 18.9) from the confluence (Jones and Stokes 2004). The mainstem portion of Battle Creek flows approximately 27.3 km (17 miles) west from the confluence of the two forks to the Sacramento River east of Cottonwood, California. The entire watershed encompasses an area of approximately 93,200 ha (360 $miles^2$; Jones and Stokes 2004). The current 39 km (24.4 miles) of anadromous fishery in Battle Creek encompasses that portion of the creek from the Eagle Canyon Dam on North Fork Battle Creek and Coleman Dam on South Fork Battle Creek to its confluence with the Sacramento River (Figure 1). Historically, the anadromous fishery exceeded 85 km (53 miles).

Battle Creek has the highest base flows of any of the Sacramento River tributaries between Keswick Dam and the Feather River, and flows are influenced by both precipitation and spring flow from basalt formations (Jones and Stokes 2005). The average flow in Battle Creek is approximately 14.1 m^3/s (500 cfs; Jones and Stokes 2004). South Fork Battle Creek is more influenced by precipitation and likely experiences higher peak flows, whereas North Fork Battle Creek receives more of its water from snow melt and spring-fed tributaries. Maximum discharge usually occurs from November to April as a result of heavy precipitation. Average annual precipitation in the watershed ranges from about 64 cm (25 inches) at the Coleman Powerhouse to more than 127 cm (50 inches) at the headwaters, with most precipitation occurring between November and April (Ward and Kier 1999). Ambient air temperatures range from about 0ºC (32ºF) in the winter to summer highs in excess of 46ºC (115ºF).

Land ownership in the Battle Creek watershed is a combination of state, federal, and private including the CDFG, Bureau of Land Management (BLM), and USFWS. Most of the land within the restoration area is private and zoned for agriculture, including grazing. Currently, much of the lower Battle Creek watershed is undeveloped, with scattered private residences, ranching enterprises, and local entities.

The Red Bluff Fish and Wildlife Office installed and operated two rotary screw traps on Battle Creek, the first site was located 4.5 km (rm 2.8) upstream of the confluence with the Sacramento River, and the second site was located 9.5 km (rm 5.9) upstream of the confluence (Figure 1). The lower trap site was designated Lower Battle Creek (LBC) and the upper trap site was designated Upper Battle Creek (UBC). The stream substrate at these locations is primarily composed of gravel and cobble, and the riparian zone vegetation is dominated by California sycamore (*Plantanus racemosa*), alder (Alnus spp.), Valley Oak (*Quercus lobata*), Himalayan blackberry (*Rubus discolor)*, California wild grape (*Vitis Californica*) and other native and non-native species.

Methods

Trap Operation

In October 2004, the Red Bluff Fish and Wildlife Office continued the operation of two rotary screw traps on Battle Creek. During the current reporting period (October 1, 2004 through September 30, 2005), the Lower Battle Creek trap (LBC) was operated from December 2, 2004 through August 3, 2005 while the Upper Battle Creek trap (UBC) was operated from October 1, 2004 through September 30, 2005. September 30, 2005 was designated the end of the current reporting period as it allowed us to estimate total passage for brood year 2004 (BY04) spring and fall Chinook salmon and total catch for BY04 winter Chinook salmon at the LBC trap. Although the designated reporting period may not include the total passage of brood year 2005 (BY05) late-fall Chinook salmon, complete passage estimates are reported as the data were available and it will prevent duplication in the 2005-2006 report.

The rotary screw traps, manufactured by E.G. Solutions® in Corvallis, Oregon, consist of a 1.5-m diameter cone covered with 3-mm diameter perforated stainless steel screen. The cone, which acts as a sieve separating fish and debris from the water flowing through the trap, rotates in an auger-type action passing water, fish, and debris to the rear of the trap and directly into an aluminum live box. The live box retains fish and debris, and passes water through screens located in the back, sides, and bottom. The cone and live box are supported between two pontoons. Two 30 to 46-cm diameter trees on opposite banks of the creek were used as anchor points for securing each trap in the creek, and a system of cables, ropes and pulleys was used to position the traps in the thalweg.

We attempted to operate the traps 24 h per day; 7 d each week, but at times high flows, hatchery releases, and other miscellaneous problems limited our ability to operate the traps continuously (Appendices 1 and 2). In addition, when few or no salmonids were captured, we did not operate the traps or operated them on a reduced schedule (usually 5 d per week). Traps were not operated when stream flows exceeded certain levels in order to prevent fish mortality, damage to equipment, and to ensure crew safety. The traps were checked once per day unless high flows, heavy debris loads, or high fish densities required multiple trap checks to avoid mortality of captured fish or damage to equipment. In addition, to improve the accuracy of our juvenile passage indexes (JPI's), we attempted to fish high flows when most juvenile salmonids are thought to outmigrate and increase the number of mark-recapture trials, which were used to estimate trap efficiency. When flows allowed, the crews were able to access the traps by wading from the stream bank; however, during high flows access to the traps required that the crews use the cable and pulley system to pull the traps into shallow water. After or during sampling and maintenance, the traps were repositioned in the thalweg.

In October 2000 the LBC trap was modified by placing an aluminum plate over one of the two existing cone discharge ports and removing an exterior cone hatch cover (half-cone modification). As a result, half of the collected fish and debris were not discharged into the live box, but rather were discharged from the cone back into the creek. This effectively reduced our catch of both fish and debris by half, and also reduced crowding of fish in the live box by half. During the current report period, the LBC trap was operated with the half-cone modification from February 12 to March 21, 2005 to reduce capture of hatchery fish and reduce crowding during periods of high debris, and the UBC trap was operated with the half-cone modification from October 18, 2004 to February 11, 2005 to prevent fish mortality during periods of high debris. In previous years, additional modifications were made to the traps and daily operations to reduce the potential for impacts to captured fish and to improve our efficiency. Modifications to traps included increasing the size of the live boxes and floatation pontoons, and adding baffles to the live boxes.

Each time a trap was sampled, crews would sample fish present in the live box, remove debris from the cone and live box, collect environmental and trap data, and complete any necessary trap repairs. Data collected at each trap included, dates and times of trap operation, water depth at the trap site, cone fishing depth, number of cone rotations during the sample period, cone rotation time, amount and type of debris removed from the live box, basic weather conditions, water temperature, water velocity entering the cone, and turbidity. Water depths were measured to the nearest 0.03 m (0.1 feet) using a graduated staff. The cone fishing depth was measured with a gauge permanently mounted to the trap frame in front of the cone. The number of rotations of the RST cone was measured with a mechanical stroke counter (Reddington Counters, Inc., Windsor, CT) that was mounted to the trap railing adjacent to the cone. The amount of debris in the live box was volumetrically measured using a 44.0 liter (10-gallon) plastic tub. Water temperatures were continuously measured with an instream Onset Optic Stow Away® temperature data logger. Water velocity was measured as the average velocity from a grab-sample using an Oceanic® Model 2030 flowmeter (General Oceanics, Inc., Miami, Florida). The average velocity was measured for a minimum of 3 min while the live box was being cleared of debris. Water turbidity was measured from a grab-sample with a Hach® Model 2100 turbidity meter (Hach Company, Ames, Iowa). In addition, daily stream discharge data collected by the U.S. Geological Survey at the Coleman Hatchery gauging station (#11376550) was also used for trap operations and to compare discharge and downstream migration patterns. The gauge site is located below the Coleman Fish Hatchery barrier weir and approximately 0.2 km downstream of the UBC trap (Figure 1).

Biological Sampling

Juvenile sampling at the traps was conducted using standardized techniques that were generally consistent with the CVPIA's Comprehensive Assessment and Monitoring Program (CAMP) standard protocol (CVPIA 1997). Dip nets were used to transfer fish and debris from the live box to a sorting table for examination. Each day the trap was sampled, a minimum number of each fish taxa captured were counted and then depending on the species, either fork length (FL) or total length (TL) was measured. Mortalities were also counted and measured. Live fish to be measured were placed in a 3.8-L (1-gallon) plastic tub and anesthetized with a tricaine methanesulfonate (MS-222; Argent Chemical Laboratories, Inc. Redmond, Washington) solution at a concentration of 60 to 80 mg/L. After being measured, fish were placed in a 37.8-L (10-gallon) plastic tub filled with fresh water to allow for recovery before being released back into the creek. Water in the tubs was replaced as necessary to maintain adequate temperature and oxygen levels. Catch data for all fish taxa were typically summarized as either weekly totals for salmonids or season totals for non-salmonids. Due to the large numbers of juvenile salmon that were frequently encountered and project objectives, different criteria were used to sample salmon, trout, and non-salmonid species.

Chinook salmon.—When less than approximately 250 salmon were captured in the trap all salmon were counted and measured for FL (to the nearest 1 mm). The measured juvenile salmon were also assigned a life-stage classification of yolk-sac fry (C0), fry (C1), parr (C2), silvery parr (C3), or smolt (C4), and a run designation of fall, late-fall, winter, or spring. Life-stage classification was based on morphological features and run designations were based on length-at-date criteria developed by Greene (1992). Length data for all Chinook salmon runs was combined for graphical purposes as the length-at date criteria developed for the mainstem Sacramento River may not be directly applicable to the tributary populations.

When more than approximately 250 juvenile salmon were captured, subsampling was conducted. All salmon in the subsample were identified, counted, and measured. These salmon were also assigned a life-stage classification and run designation, using the methods described above. All other salmon were counted and identified. A cylinder-shaped net with 3-mm mesh and a split-bottom construction was used for subsampling. The bottom of the subsampling net was constructed with a metal frame that created two equal halves. A closed mesh bag was sewed onto one half of the frame and an open mesh bag was sewed onto the other half of the frame. The subsampling net was placed in a 117-L (30-gallon) bucket that was partially filled with creek water. All captured juvenile salmon were poured into the bucket. Once the fish had distributed evenly throughout the bucket, the net was lifted and approximately half of the salmon were retained in the side of the net with the closed mesh bag, and approximately half of the salmon in the side with the open mesh bag were retained in the bucket. We continued to successively subsample (split) until approximately 150 to 250 individuals remained in a subsample. The number of successive splits that we used varied with the number of salmon collected. Subsampling was used to obtain a representative sample for measuring. To determine total catch, we counted all salmon in each split. Chinook salmon biological data were summarized by brood year for each run designation.

Rainbow trout/steelhead.—Due to the smaller numbers encountered, all rainbow trout/steelhead captured in the traps were counted and FL measured to the nearest 1 mm. Life stages of juvenile trout were classified similarly as salmon, as requested by the Interagency Ecological Program (IEP) Steelhead Project Work Team. All live rainbow trout/steelhead >50 mm captured at both traps were weighed to the nearest 0.1 g for CDFG's Stream Evaluation Program.

Non-salmonid taxa.—All non-salmonid taxa that were captured were counted, but each day we only measured up to approximately 30 randomly selected individuals for each taxa. Total length was measured for lamprey *Lampetra spp.,* sculpin *Cottus spp.*, and western mosquitofish (*Gambusia affinis*); otherwise, FL was measured for all other non-salmonid taxa. Non-salmonids were not the focus of this monitoring project, therefore only total catch by species is provided in this report but length data is available.

Trap Efficiency and Juvenile Salmonid Passage

One of the goals of our monitoring project was to estimate the number of juvenile salmonids passing downstream in a given unit of time, usually a week and brood year. We defined this estimate the juvenile passage index (JPI). Since each trap only captures fish from a small portion of the creek cross section, we used trap efficiencies, which were determined using mark-recaptured methods, and the weekly catch to estimate weekly and annual JPI's. For days when the trap was not fishing, daily catch was estimated by averaging an equal number of days before and after the days not fished. For example, if the trap did not fish for 2 d, the daily catch for those days was estimated by averaging catch from 2 d before and 2 d after the period the trap did not fish. However, if one of the days before or after was also a missed day, it was usually not used to estimate other missed days. For example, if the trap did not fish for 3 d, but one of the 3 days before was also a missed day, then catch from the 2 d before and 3 d after the missed period were used to estimate catch.

During the current reporting period, late-fall Chinook salmon released by Coleman National Fish Hatchery (CNFH) in November 2004 and January 2005 were all marked with an adipose-fin clip; therefore, when they were captured in the trap, they were subtracted from the daily catch. However, in April 2005 no fall Chinook salmon released above the LBC trap by CNFH were marked; therefore, from April 19 to late-June when they were captured in the LBC trap, most Chinook salmon >59 mm were classified as hatchery fish and were not included in the daily count.

Mark-recapture trials.— Mark-recapture trials were conducted to estimate trap efficiency. Ideally, separate mark-recapture trials should be conducted for each species, run, and life-stage to estimate species and age-specific trap efficiencies. However, catch rates for steelhead, spring, winter, and late-fall Chinook salmon were too low to conduct separate trials; therefore, trap efficiencies were estimated using primarily fall Chinook salmon fry, but late-fall Chinook fry and larger fish were used for a few trials. We attempted to use only naturally-produced (unmarked, unclipped, and untagged) juvenile salmon for mark-recapture trials. However, when trap catches were insufficient in March and April, some hatchery fish that were captured in the LBC trap were used for mark-recapture trials. Marked Chinook salmon that were recaptured in the traps were counted, measured, and subsequently released downstream of the trap to prevent them from being recaptured again.

During the 2004 to 2005 season, two marks were used during all 28 trials conducted at the LBC trap. To apply the first mark, juvenile salmon were immersed in Bismark brown-Y stain (J. T. Baker Chemical Company, Phillipsburg, New Jersey) for 50 min at a concentration of 8 g/380 L of water (211 mg/L). When air temperatures were high in late spring and summer, a portable water chiller unit was used to maintain ambient stream temperatures and reduce stress and mortality during the staining process. For the second mark, Bismark brown stained salmon were anesthetized with an MS-222 solution at a concentration of 60 to 80 mg/L. Once the Bismark brown stained fish were anesthetized, lower-caudal fin-clips were applied using scissors to remove a small portion of the lower caudal fin. Marked fish were placed in a live-car and allowed to recover. Two mark-recapture trials were conducted at the LBC trap during most weeks; however, when the numbers of salmon available for marking were low, only one trial was conducted each week at LBC. All salmon marked for LBC trials were released at the Jelly's Ferry Bridge which is located approximately 1.3 km (0.8 mi) upstream of the trap (Figure 1). Trials conducted at the UBC trap were done using methods similar to those used for the LBC trap (Bismark brown). During 29 of the 30 trials conducted at the UBC trap, an upper-caudal fin-clip was applied to allow field crews to differentiate between fish released for trials at the LBC trap. Only one mark was used during the second trial, but since only one fish was recaptured and the cone was not rotating the day after the release, the trial results were not used. Two mark-recapture trials were conducted at the UBC trap during most weeks; however, when the numbers of salmon available for marking were low, only one trial was conducted each week. All fish marked for UBC trials were released at the Coleman National Fish Hatchery's Intake 3 located 1.6 km (1.0 mi) upstream of the UBC trap (Figure 1). Although not presented in this report, we measured the fork length of about 30 to 60 marked salmon prior to release, and then measured all of the recaptured salmon to make comparisons between marked fish released and marked fish recaptured. Marked fish were generally held overnight and released the next day. Prior to release, mortalities and injured fish were removed and the remaining fish were counted and released. During most trials, marked fish were released after dark or at dusk to reduce the potential for unnaturally high predation on salmon that may be temporarily disorientated during transportation, and to simulate natural populations of outmigrating Chinook salmon which move downstream primarily at night (Healey 1998; J. T. Earley, USFWS, RBFWO, unpublished data).

Trap efficiency.—Trap efficiency was estimated using a stratified Bailey's estimator, which is a modification of the standard Lincoln-Peterson estimator (Bailey 1951; Steinhorst et al. 2004). The Bailey's estimator was used as it performs better with small sample sizes and is not undefined when there are zero recaptures (Carlson et al. 1998; Steinhorst et al. 2004). In addition, Steinhorst et al. (2004) found it to be the least biased of three estimators. Trap efficiency was estimated by

$$\hat{E}_h = \frac{(r_h + 1)}{(m_h + 1)}, \qquad (1)$$

where m_h is the number of marked fish released in week h and r_h is the number of marked fish recaptured in week h. Although trap efficiency was calculated for all mark-recapture trials, only those trials with at least seven recaptures were used as suggested by Steinhorst et al. (2004). Occasionally if a mark-recapture trial had less than seven recaptures, but the estimated trap efficiency and the mean weekly stream flows were similar to adjacent week(s), the number of marks and recaptures were pooled prior to estimating trap efficiency. Otherwise, a season average efficiency was used to estimate the JPI during weeks where there were less than seven recaptures or during weeks when no mark-recapture trials were conducted. The season average efficiency was based on all trials with more than seven recaptures, unless there were trials that had been pooled, in which case the pooled results were used when calculating the season average efficiency. If two mark-recapture trials were conducted during the same week, the results were combined to calculate the average weekly trap efficiency.

During the 2004 to 2005 season, a half-cone modification used to reduce impacts from crowding and high debris loads at both traps influenced the results of mark-recapture trials conducted during that time. At the LBC trap, 28 mark-recapture trials were conducted during the season, 11 of which occurred while the trap had the half-cone modification; therefore the trial results were not equivalent to those conducted at full-cone. At the UBC trap, 30 mark-recapture trials were conducted during the season, 9 of which occurred while the trap was operating at with the half-cone modification. To calculate production estimates for weeks when both traps were at full cone and no mark-recapture trials were conducted, the full-cone season average trap efficiency was estimated using the results of all valid pooled and unpooled trials (>7 recaptures) done at full-cone, and then doubling efficiency for all valid pooled and unpooled trials conducted at half-cone. In contrast, the season average trap efficiency used for weeks when the trap was operated with the half-cone modification was estimated using the results of the trials done at half-cone, and then halving the efficiency of trials done at full-cone. By either doubling the half-cone trap efficiency or halving the full-cone efficiency, we were able to estimate either a half-cone or full cone season trap efficiency based on all valid trials. During one week at each trap, one mark-recapture trial was done while the trap was at half-cone and one was done while the trap was at full-cone. To allow pooling to calculate weekly trap efficiencies, the numbers of recaptures for the half-cone trials were doubled to make the two trials equivalent. In addition, catch was doubled for days the traps were operated at half-cone during the week. At the LBC trap, the half-cone season trap efficiency was not used to estimate passage because mark-recapture trials were conducted during all weeks the trap was operated with the half-cone modification.

Juvenile passage index(JPI).— Weekly JPI estimates for Chinook salmon and rainbow trout/steelhead were calculated using weekly catch totals and either the weekly trap efficiency, pooled trap efficiency, or average season trap efficiency. Juvenile Chinook salmon JPI's at LBC and UBC were summarized by brood year where the weekly catch for each run of Chinook salmon included all life-stages from a single brood year. Rainbow trout/steelhead were summarized as either young-of-the-year (yoy) or age 1+, which included individuals from all other age classes The fork length distribution (fork length by date) of rainbow trout/steelhead captured in either trap was used to determine weekly catch of young-of-the-year and age 1+. With few exceptions, graphical display of fork length distribution indicated a distinct separation of the two groups. In addition, age 1+ and young-of-the-year rainbow trout/steelhead captured during the same week could usually be distinguished by their life-stage classification.

The season was stratified by week because as Steinhorst et al. (2004) found, combining the data where there are likely changes in trap efficiency throughout the season leads to biased estimates. Using methods described by Carlson et al. (1998) and Steinhorst et al. (2004), the weekly JPI's were estimated by

$$\hat{N}_h = \frac{U_h}{\hat{E}_h}, \tag{2}$$

where U_h is the unmarked catch during week *h*. The total JPI for the year is then estimated by

$$\hat{N} = \sum_{h=1}^{L} \hat{N}_h \tag{3}$$

where *L* is the total number of weeks. Variance and the 90 and 95% confidence intervals for $\hat{N}_h$ each week were determined by the percentile bootstrap method with 1,000 iterations (Efron and Tibshirani 1986; Buckland and Garthwaite 1991; Thedinga et al. 1994; Steinhorst et al. 2004). Using simulated data with known numbers of migrants, and trap efficiencies, Steinhorst et al. (2004) determined the percentile bootstrap method for developing confidence intervals performed the best, as it had the best coverage of a 95% confidence interval. Each bootstrap iteration involved first drawing 1,000 r^*_{hj} (j=1, 2…, 1000; asterisk indicates bootstrap simulated values) from the binomial distribution (m_h, $\hat{E}_h$)(Carlson et al.

1998) and then calculating 1,000 $\hat{N}*_{hj}$ using equations (1) and (2), replacing r_h with $r*_{hj}$. The 1,000 bootstrap iterations of the total JPI ($\hat{N}*_{j}$) were calculated as

$$\hat{N}*_{j} = \sum_{h=1}^{L} \hat{N}*_{hj} \ . \tag{4}$$

As described by Steinhorst et al. (2004), the 95% confidence intervals for the weekly and total JPI's were found by ordering the 1,000 $\hat{N}*_{hj}$ or $\hat{N}*_{j}$ and locating the 25th and 975th values. Similarly, the 90% confidence intervals for the weekly and total JPI's were found by locating the 50th and 950th values of the ordered iterations. Ordering was not performed until after the $\hat{N}*_{j}$ were derived. The variances for $\hat{N}_h$ and $\hat{N}$ were calculated as the standard sample variances of the 1,000 $\hat{N}*_{hj}$ and $\hat{N}*_{j}$, respectively (Buckland and Garthwaite 1991).

Results

Trap Operation

Lower Battle Creek (LBC).— During the current reporting period, the LBC trap was operated continuously from December 2, 2004 to August 3, 2005, except during high flows, hatchery releases, and periods of reduced sampling in July (Appendix 1). The trap was not operated in October and November 2004 and from August 4 to September 30, 2005 because there was little or no salmonid catch. Of the 365 d available during the sample period, the trap was operated 228 d. Reduced sampling (e.g., sampling 4 or 5 d per week) due to limited or no salmonid catch was responsible for 124 of the missed sample days (90%), high flows accounted for about 8 d (6%), and hatchery releases accounted for 5 d (4%). Monthly sampling effort from December 2004 through August 2005 varied from a low of 10% in August 2005 to a high of 100% for February, March, and June 2005 (Figure 2).

Mean daily water temperatures at the LBC trap varied from a low of 6.2ºC (43.2ºF) on January 8, 2005 to a high of 22.1ºC (71.7ºF) on July 20, 2005 (Figure 3). Mean daily flow that was measured by the U.S. Geological Survey at the Coleman Hatchery gauging station (#11376550) varied from a low of 5.5 m^3/s (196 cfs) on September 5, 2005 to a peak mean daily flow of 59.0 m^3/s on May 19, 2005 (2,083 cfs; Figure 3). A maximum flow of 103.1 m^3/s (3,640 cfs) occurred at the USGS gauge station on May 9, 2005. Turbidity, which was measured only while the LBC trap was operated, varied from lows <1.0 NTU's for several days in December to a peak of 8.6 NTU's on February 28, 2005 (Figure 3). In general, turbidity increased with increasing flows, but increases in turbidity did not always appear to be related to similar increases in flow (Figure 3). However, turbidity was only measured when the trap was operating; therefore, it is likely that turbidity was higher during the high flow events.

Upper Battle Creek (UBC).— During the current reporting period, the UBC trap was operated continuously from October 1, 2004 to September 30, 2005, except during high flows and periods of reduced sampling in July through September 2005 (Appendix 2). Of the 365 d available during the report period, the trap was operated about 337 d. Reduced sampling due to limited or no salmonid catch accounted for 20 of the missed sample days (71%) and high flows accounted for the remaining 8 d (29%). The monthly sampling effort from October 2004 through September 2005 varied from a low of 73% in September 2005 to a high of 100% in several months during the sample period (Figure 2; Appendix 2).

Mean daily water temperatures at the UBC trap varied from a low of 6.2ºC (43.1ºF) on January 8, 2005 to a high of 21.0ºC (69.7ºF) on July 20, 2005 (Figure 4). Mean daily flows for the UBC trap are the same as those reported for LBC trap as the same gauging station was used (Figure 4). Turbidity at the UBC trap varied from several days <1.0 NTU's in October and November 2004 to a high of 11.4 NTU's on February 20, 2005 (Figure 4). In general, turbidity increased with increasing flows, but increases in turbidity did not always appear to be related to similar increases in flow (Figure 4). However, turbidity was only measured when the trap was operating; therefore, it is likely that turbidity was higher during the high flow events.

Biological Sampling

Spring Chinook salmon-LBC.—Brood year 2004 (BY04) spring Chinook salmon were first captured at the LBC trap the week of December 7, 2004 with a peak weekly catch of 108 the week of March 22, 2005 (Figure 5). The last spring Chinook salmon was captured the week of April 12, 2005. The BY04 spring Chinook salmon total catch based on the length-at-date criteria was 416. However after adjusting the total catch for days the trap was not operated, the adjusted total catch was 422.

Fork lengths of spring Chinook salmon sampled at the LBC trap varied from 37 to 106 mm with a mean of 73 mm (N=392; Figure 6). Length frequency data for all runs were combined because run designations were determined using length-at-date-criteria developed for the Sacramento River (Green 1992; Figure 7). In Battle Creek, there is overlap in fork lengths between runs, but the overlap appears to be a particular problem with spring and fall Chinook salmon. The life-stage composition of spring Chinook salmon captured at the LBC trap was 0% yolk-sac fry, 22.5% fry, 7.4% parr, 41.8% silvery parr, and 28.3% smolt (Table 1).

Fall Chinook salmon - LBC.—Fall Chinook salmon were the most abundant salmonid captured at the LBC trap. Brood year 2004 fall Chinook salmon were first captured at the trap the week of November 30, 2004 (Figure 5). Following their initial capture, the numbers of fall Chinook salmon increased rapidly to a peak weekly capture of 100,970 the week of February 8, 2005. A second smaller peak weekly catch of 1,121 occurred the week of April 5, 2005. The total number of BY04 fall Chinook salmon captured in the LBC trap on days that it was operated was 236,006. After adjusting the total catch reported above for days the trap was not operated, the adjusted total catch of BY04 fall Chinook salmon at the LBC trap was 237,066.

Fall Chinook salmon fork lengths ranged from 19 to 81 mm during the reporting period, with a mean fork length of 38 mm (N=19,203; Figure 6). Length frequency data for all runs were combined because run designation was determined by length-at-date-criteria developed for the Sacramento River (Green 1992; Figure 7). Length frequency histograms for Chinook salmon were highly skewed towards newly emerging fry ≤40 mm (80%; Figure 7). Fall Chinook salmon fry comprised the largest portion of these fish as they were the most abundant run captured at the LBC trap. All five life-stages of fall Chinook salmon were captured during the reporting period (Table 1). Of the fall Chinook salmon sampled at the LBC trap, yolk-sac fry were 12.5%, fry were 76.2%, parr were 7.8%, silvery parr 3.3%, and smolt 0.2%.

Late-fall Chinook salmon - LBC.—Individuals from two brood years of late-fall Chinook salmon (BY04 and BY05) were captured at the LBC trap between October 1, 2004 and September 30, 2005; however, only two BY04 late-fall Chinook salmon were captured in the trap during the reporting period. Brood year 2004 late-fall Chinook salmon weekly and annual passage estimates were reported in the 2003-2004 report (Whitton et al. 2007c). Brood year

2005 late-fall Chinook salmon were first captured in the trap the week of March 29, 2005 with a peak weekly capture of 1,059 the week of May 3, 2005 (Figure 5). The last week of capture was July 5, 2005. No additional late-fall Chinook salmon were captured during the 3 months following the reporting period, but the trap was not operated from October 1 to December 7, 2005. Using length-at-date criteria, the actual catch of BY05 late-fall Chinook salmon in the LBC trap was 2,949. After adjusting total catch for days the trap was not operated, the adjusted total catch of BY05 late-fall Chinook salmon was 3,383.

Fork lengths of late-fall Chinook salmon captured at the LBC trap varied from 26 to 108 mm with a mean fork length of 35 mm (N=2,705; Figure 6). Length frequency histograms which included all runs of Chinook salmon were highly skewed towards newly emerging fry ≤40 mm (Figure 7). The life-stage composition of late-fall Chinook salmon sampled at the LBC trap was 2.5% yolk-sac fry, 94.3% fry, 3.1% parr, 0.1% silvery parr, and 0% smolt (Table 1).

Winter Chinook salmon - LBC.—Winter Chinook salmon were first captured at the LBC trap the week of November 30, 2004 with the peak weekly catch of 301 occurring the week of February 8, 2005 (Figure 5). The last day winter Chinook were captured at the trap was April 5, 2005. Winter Chinook are likely migrants from the Sacramento River using lower Battle Creek for non-natal rearing. The total catch based on the length-at-date criteria was 441. However after adjusting the total catch for days the trap was not operated, the adjusted total catch was 445.

Fork lengths of winter Chinook salmon sampled at the LBC trap varied from 62 to 134 mm with a mean of 96 mm (N=26; Figure 6). Fork length frequency data for winter Chinook salmon was combined with other runs for graphical display (Figure 7). The life-stage composition of winter Chinook salmon sampled at the trap was 52.0% silvery parr and 48.0% smolt (Table 1). No other life-stages were captured.

Rainbow trout/steelhead - LBC.—During the reporting period 20 age 1+ and 126 young-of-the-year (yoy) rainbow trout/steelhead were captured at the LBC trap. Rainbow trout/ steelhead were first captured at the LBC trap the week of November 30, 2004 with a peak weekly capture of 38 occurring the week of March 1, 2005 (Figure 8). The actual rainbow trout catch at the LBC trap was 138; however, after adjusting the total catch for days the trap was not operated, the adjusted total catch was 146.

Fork lengths of young-of-the-year (yoy) rainbow trout/steelhead ranged from 25 to 82 mm with a mean of 36 mm and a median of 28 mm (N= 119; Figures 9 and 10). The range in fork lengths of yoy trout accounts for growth over time. Fork lengths of age 1+ trout ranged from 151 to 379 mm with a mean and median of 234 mm and 219 mm, respectively (Figures 9 and 10). The length frequency histogram for trout was skewed towards newly emerging fry ≤30 mm which accounted for 56% all trout captured in the LBC trap (Figure 10). Rainbow trout/steelhead fry (52.9%) and parr (31.9%) were the most abundant life-stages sampled at the LBC trap, while yolk-sac fry, silvery parr, and smolt were the least abundant (4.3, 5.1, and 5.8%; Table 1).

Non salmonids - LBC.—From December 2, 2004 through August 3, 2005, 10 native non-salmonid species were sampled at the LBC trap including, California roach *Hesperoleucus symmetricus* (N=9), speckled dace *Rhinicthys osculus* (N=24), hardhead *Mylopharodon conocephalus* (N=211), Pacific lamprey *Lampetra tridentata* (N=450), prickly sculpin *Cottus asper* (N=16), riffle sculpin *Cottus gulosus* (N=199), Sacramento pikeminnow *Ptychocheilus grandis* (N=57), Sacramento sucker *Catostomus occidentalis* (N=422), tule perch *Hysterocarpus traski* (N=56), and threespine stickleback *Gasterosteus* aculeatus (N=11). In addition, three introduced non-salmonids were also captured in the LBC trap including, green sunfish *Lepomis cyanellus* (N=30), largemouth bass *Micropterus salmoides* (N=7), and western mosquitofish *Gambusia affinis* (N=1). Next to Chinook salmon, Pacific lamprey and Sacramento suckers were the next most abundant species captured in the traps. In addition, several unidentified centrachid, cottid, cyprinid, and lamprey fry were also captured in the trap.

Spring Chinook salmon - UBC.—Brood year 2004 spring Chinook salmon were first captured at the UBC trap the week of November 16, 2004 with a peak weekly catch of 24 the week of December 14, 2004 (Figure 11). A secondary peak of 19 occurred the week of March 29, 2005. The last BY04 spring Chinook salmon was captured the week of May 17, 2005. The BY04 spring Chinook salmon total catch based on the length-at-date criteria was 128. However after adjusting the total catch for days the trap was not operated, the adjusted total catch was 129.

The fork length of spring Chinook salmon sampled at the UBC trap varied from 25 to 124 mm with a mean fork length of 71 mm, respectively (N=124; Figure 12). Length frequency for all runs was combined because run designation was determined by the length-at-date-criteria developed for the Sacramento River, and there is overlap between runs, particularly between spring and fall Chinook salmon (Green 1992; Figure 13). The life-stage composition of spring Chinook salmon sampled at the UBC trap was 1.7% yolk-sac fry, 34.7% fry, 1.7% parr, 17.3% silvery parr, and 44.6% smolt (Table 1).

Fall Chinook salmon - UBC.—Fall Chinook salmon were the most abundant salmonid captured at the UBC trap. Brood year 2004 fall Chinook salmon were first captured in the trap the week of December 7, 2004 with the peak weekly catch of 218 occurring the week of December 28, 2004 (Figure 11). Following their initial capture, the numbers of fall Chinook salmon increased rapidly and were captured every week until the week of May 31, 2005 (Figure 11). One additional fall Chinook salmon was captured the week of August 2, 2005. The total number of BY04 fall Chinook salmon captured in the UBC trap on days that it was operated was 860. After adjusting the total catch reported above for days the trap was not operated, the adjusted total catch of BY04 fall Chinook salmon at the UBC trap was 962.

Fork lengths of fall Chinook salmon sampled at the UBC trap varied from 30 to 96 mm with a mean of 37 mm (N=865; Figure 12 and 13). Length frequency histograms for Chinook salmon were highly skewed towards newly emerging fry ≤40 mm (80%; Figure 13). Fall Chinook salmon fry comprised the largest portion of these fish as they were the most abundant run of Chinook salmon captured at the UBC trap. The life stage composition of fall Chinook salmon sampled at the UBC trap was 1.3% yolk-sac fry, 95.0% fry, 0.8% parr, 1.3% silvery parr and 1.6% smolt (Table 1).

Late-fall Chinook salmon - UBC.—Unlike previous years, individuals from one rather than two brood years of late-fall Chinook salmon (BY04 and BY05) were captured at the UBC trap between October 1, 2004 and December 31, 2005. No BY04 late-fall Chinook salmon were captured in the UBC trap during the sample period; however, they were summarized in the 03-04 report. Brood year 2005 late-fall Chinook were first captured in the trap the week of April 5, 2005 with a peak weekly capture of four the same week. Total catch of late-fall was much lower than in the previous 3 years (N=7). The last week a BY05 late-fall Chinook salmon was captured was May 10, 2005, and no additional BY05 late-fall Chinook salmon were captured after the report period. Using length-at-date criteria, the BY05 late-fall Chinook salmon total catch was 6. After adjusting the total catch for days the trap was not operated, the adjusted total catch of BY05 late-fall Chinook salmon was 7.

Fork lengths of late-fall Chinook salmon captured at the UBC trap varied from 31 to 42 mm with a mean fork length of 34 mm (Figure 12). Length frequency histograms which included all runs of Chinook salmon were highly skewed towards newly emerging fry ≤40 mm (Figure 13). During the current reporting period, the life-stage composition of BY05 late-fall Chinook salmon sampled at the UBC trap was 83.3% fry and 16.7% parr; however, only six late-fall Chinook salmon were measured at the trap (Table 1).

Winter Chinook salmon - UBC.—During the reporting period, only four winter Chinook salmon were captured in the UBC trap; therefore, no additional information will be reported for this race.

Rainbow trout/steelhead - UBC.—During the reporting period, 24 age 1+ and 212 young-of-the-year (yoy) rainbow trout/steelhead were captured at the UBC trap. They were first captured the week of October 19, 2004 with a peak weekly capture of 56 occurring the week of May 10, 2005 (Figure 14). The actual rainbow trout catch at the UBC trap was 216; however, after adjusting the total catch for days the trap was not operated, the adjusted total catch was 236.

Fork lengths of young-of-the-year (yoy) rainbow trout/steelhead ranged from 23 to 171 mm with a mean of 58 mm and a median of 60 mm (N=200; Figures 15 and 16). The range in fork lengths of yoy trout accounts for growth over time. Fork lengths of age 1+ trout ranged from 106 to 329 mm with a mean of 212 mm and a median of 214 mm (N=24; Figures 15 and 16). The length frequency histogram for trout was somewhat skewed towards newly emerging fry ≤30 mm, but trout > 30 mm were 83% of all trout captured at the UBC trap (Figure 16). Rainbow trout/steelhead fry (19.6%) and parr (62.5%) were the most abundant life-stages sampled at the UBC trap, whereas silvery parr, smolt, and yolk-sac fry were the least abundant (12.5, 5.4, and 0%; Table 1).

Non salmonids - UBC.—From October 1, 2004 through September 30, 2005, 11 native non-salmonid species were captured in the UBC trap, including California roach (N=6), speckled dace (N=6), hardhead (N=420), Pacific lamprey (N=420), Pacific brook lamprey *Lampetra pacifica* (N=1), prickly sculpin (N=1), riffle sculpin (N=168), Sacramento pikeminnow (N=69), Sacramento sucker (N=2,559), tule perch (N=35), and threespine stickleback (N=10). In addition, two introduced non-salmonid species were captured, including green sunfish (N=1) and smallmouth bass *Micropterus dolomieu* (N=1). Cottid, cyprinid, micropterus, and lamprey fry were also captured at the trap, but could not be identified to species. Sacramento suckers were the most abundant species captured at the trap with Chinook salmon being the second most abundant.

Trap Efficiency and Juvenile Salmonid Passage

Lower Battle Creek trap efficiency (LBC).—To estimate trap efficiency, 28 mark-recapture trials were conducted at the LBC trap (Table 2). We released marked Chinook salmon during 17 of the 34 weeks that salmonids were captured at the LBC trap (December 2, 2004 through July 27, 2005). The results of two trials were not used to calculate passage because one only had one recapture because a crew error occurred the day after marked fish were released (January 28, 2005), and the other had no recaptures (May 13, 2005). Of the 26 trials that were used to calculate passage, 20 had at least seven recaptures as recommended by Steinhorst et al. (2004). Three trials with less than seven recaptures were each one of two trials conducted during the same week; therefore, the results of each trial were pooled with the other trial conducted that week (March 18, 22, and 25, 2005). The other three trials with less than seven recaptures were pooled with trials from an adjacent week(s) (April 19, 26, and May 6, 2005). During nine of the weeks that trials were conducted, two separate mark-recapture trials were conducted and the results were pooled prior to calculating the weekly trap efficiency. During the remaining 8 weeks, only one trial was conducted. Weekly trap efficiencies for the valid pooled and unpooled trials varied from 0.022 to 0.101 for full and half-cone trials combined. Using the results of these trials, the half-cone season average trap efficiency was estimated at 0.032 and the full-cone season average trap efficiency was 0.063. The half-cone season average trap efficiency was not used to estimate weekly passage because a mark-recapture trial was conducted during each week the trap was operated with the half-cone modification. However, the full-cone season trap efficiency was used to estimate passage during 17 weeks when the trap was operated at full-cone and no mark-recapture trials were conducted or when trial results were not used.

Upper Battle Creek trap efficiency (UBC).—To estimate trap efficiency, 30 mark-recapture trials were conducted at the UBC trap (Table 3). We released marked Chinook salmon during 19 of the 35 weeks that salmonids were captured at the UBC trap (October 20, 2004 to September 21, 2005). The results of one trial were not used to calculate passage because there was only one recapture because the cone was not rotating the day after marked fish were released (January 11, 2005). Of the 29 trials that were used to calculate passage, 20 had at least seven recaptures as recommended by Steinhorst et al. (2004). Two trials with less than seven recaptures were pooled with each other as they were conducted during adjacent weeks and efficiencies and mean flows were similar (January 4 and 14, 2005). Three trials from two adjacent weeks were pooled because flows and trap efficiencies were similar (March 22, 25, and April 1, 2005). Three trials from three adjacent weeks with less than seven recaptures were pooled with each other because trap efficiencies were similar (April 29, May 6 and 13, 2005). The mean weekly flows during the 3 weeks were different, but because the trap efficiencies were about half of the estimated season average trap efficiency, we chose to pool the weeks. The remaining two trials with less than seven recaptures were one of two trials conducted during the same week (January 24 and April 5, 2005); therefore, the results were pooled with the other trial conducted that week. During 11 of the weeks that trials were conducted, two separate mark-recapture trials were conducted and the results were pooled prior to calculating weekly passage. During all other weeks, either one or no trial was conducted. Weekly trap efficiencies for the pooled and unpooled trials varied from 0.023 to 0.089 for full and half-cone trials combined. Using the results of these trials, the half-cone season average trap efficiency was estimated at 0.032 and the full-cone season average trap efficiency was 0.065. The half-cone season average trap efficiency was used to estimate weekly passage during 6 weeks when the trap was operated with the half-cone modification and no mark-recapture trials were conducted. The full-cone season trap efficiency was used to estimate passage during 10 weeks when the trap was operated at full-cone and no mark-recapture trials were conducted.

Lower Battle Creek juvenile salmonid passage (LBC).—At the LBC trap, trap efficiency estimates were used to generate juvenile passage indexes (JPI) for spring, fall, and late-fall Chinook salmon and rainbow trout/steelhead. Although juvenile passage indexes were calculated for spring Chinook salmon, they are likely unreliable (i.e., low) because of the overlap in length with fall Chinook salmon. Juvenile passage index estimates were not calculated for winter Chinook salmon as they are likely migrants from the Sacramento River using lower Battle Creek as non-natal rearing habitat.

The annual JPI for BY04 spring Chinook salmon was 7,983 and the 90 and 95% confidence intervals were 6,434 to 10,015 and 6,256 to 10,884, respectively (Table 4). A peak weekly passage of 2,808 occurred the week of March 22, 2005 although a smaller peak of 60 occurred earlier the week of December 14, 2004. These two peaks represent the initial movement of fry out in December, and then larger fish (parr, silvery parr, and smolt) in March and April. The annual JPI for BY04 fall Chinook salmon was 4,349,127 (Table 5). The 90 and 95% confidence intervals for the annual JPI were 3,822,231 to 4,993,838 and 3,724,470 to 5,174,112, respectively. The weekly JPI's for fall Chinook salmon increased rapidly to a peak of 1,256,036 the week of February 15, 2005, and then began to decrease until late-March when passage increased for a short time. The annual JPI for BY05 late-fall Chinook salmon was 69,169 (Table 6). The 90 and 95% confidence intervals for the annual JPI were 55,279 to 88,536 and 53,440 to 92,898, respectively. The weekly JPI's for late-fall Chinook salmon increased quickly to a peak of 26,956 the week of May 3, 2005. Passage estimates for BY04 late-fall Chinook salmon are not reported here because only a small portion of the run was sampled during the current reporting period. Rather, passage estimates for BY04 late-fall Chinook salmon were summarized in the 2003-2004 report (Whitton et al. 2007c). The annual JPI for age 1+ rainbow trout/steelhead passing the LBC trap between December 2, 2004 and August 3, 2005 was 357 while passage for yoy trout was 3,422 (Table 7). The 90 and 95% confidence intervals for the annual JPI for age 1+ fish were 291 to 447 and 284 to 469, respectively. The 90 and 95% confidence intervals for the yoy annual JPI estimate were 2,809 to 4,289 and 2,739 to 4,682, respectively. Most age 1+ fish migrated between early December and late May with a peak weekly passage of 82 the week of April 5, 2005. In contrast, yoy were not captured in the trap until mid-February with a peak weekly passage of 1,758 the week of March 1, 2005.

Upper Battle Creek juvenile salmonid passage (UBC).—At the UBC trap, trap efficiency estimates were used to generate juvenile passage indexes (JPI) for spring, fall, and late-fall Chinook salmon and rainbow trout/steelhead. Although juvenile passage indexes were calculated for spring Chinook salmon, they are likely unreliable (i.e. low) because of the overlap in length with fall Chinook salmon and small sample sizes. Juvenile passage indexes were not calculated for winter Chinook salmon because only one was captured in the trap.

The annual JPI for BY04 spring Chinook salmon was 3,253, and the 90 and 95% confidence intervals were 2,803 to 3,835 and 2,748 to 3,996, respectively (Table 8). A peak weekly passage of 750 occurred the week of December 14, 2004, with a second peak (N=507) occurring the week of March 29, 2006. These two peaks represent the initial movement of fry out in December, and then larger fish (parr, silvery parr, and smolt) in March and April. The annual JPI for BY04 fall Chinook salmon at the UBC trap was 26,763, and the 90 and 95% confidence intervals were 22,614 to 32,162 and 22,131 to 33,695, respectively (Table 9). The weekly JPI's for fall Chinook salmon increased rapidly to a peak of 6,813 the week of December 28, 2004 and then mostly decreased until late-April when passage increased to a second peak (N=349) the week of May 3, 2005. The annual JPI for BY05 late-fall Chinook salmon was 147 and the 90 and 95% confidence intervals for the were 112 to 198 and 109 to 213, respectively (Table 10). Passage of late-fall Chinook salmon was much lower than in previous years, with a peak passage of 70 the week of May 10, 2005. No additional late-fall Chinook salmon were captured from October 1 to December 31, 2005. No passage estimates were made for BY04 late-fall Chinook salmon captured at the UBC trap because none were sampled during the current reporting period, and weekly and annual passage estimates for BY04 late-fall Chinook salmon at the UBC trap were summarized in the 2003-2004 report (Whitton et al. 2007c). The annual JPI for age 1+ rainbow trout/steelhead passing the UBC trap between October 1, 2004 and September 30, 2005 was 485 whereas passage for yoy trout was 5,490 (Table 11). The 90 and 95% confidence intervals for the age 1+ annual JPI estimate were 421 to 573 and 411 to 610, and the 90 and 95% confidence intervals for the annual JPI for yoy trout were 4,355 to 7,074 and 4,231 to 7,431, respectively. Most age 1+ fish migrated during mid-October through May, whereas yoy were not captured in the trap until early February with a peak weekly passage of 1,848 the week of May 10, 2005.

Discussion

Trap Operation

High flows and hatchery releases limited our ability to operate either trap continuously during the sample season. However, during peak migration we operated the traps on a more continuous basis than in most years, particularly the UBC trap which operated 93% (338 d) of the season. During the period of peak migration (November through June), the UBC trap operated 97% of the time (234 of 242 d). Reduced sampling at the UBC trap in July through September may have limited the accuracy of our annual catch totals for non-salmonids, but likely had little or no impact on our Chinook salmon and rainbow trout/steelhead estimates because previous sampling has shown that few or no salmonids are captured during this period (Whitton et al. 2006; Whitton et al. 2007a; Whitton et al. 2007b). During the period of peak migration, the LBC trap was only operated 82% of the time, but fall and spring Chinook salmon fry passage typically begins in late November to early December; therefore it is unlikely that many were missed when the trap was not operated from November 1 to December 1, 2004. The trap was not operated during this period due to the cone being clogged with slime and parts from Chinook carcasses in previous years. Passage estimates for age 1+ rainbow trout/steelhead were the most likely to have been affected as previous sampling suggests that catch for this group increases in November (Whitton et al. 2006; Whitton et al. 2007a). Annual catch totals for some species of non-salmonids captured in the LBC trap are likely low because the trap was not operated October 1 to December 1, 2004 and August 4 to September 30, 2005, which can be periods of high non salmonid catch. Increasing the number of days the traps operated during periods of Chinook salmon and rainbow trout/steelhead outmigration likely increased the accuracy of our estimates. However, estimating catch on days the traps were not operated may have affected our weekly and annual JPI's, but the magnitude of the affect likely varied with the time of the year, catch, and number of consecutive days estimated. During the reporting period, high flows prevented us from operating both traps for 8 d. The high flow events occurred during late-December to early January and mid-May which are the periods of peak outmigration for fall, spring, and late-fall Chinook salmon fry. Typically, spring and fall Chinook salmon fry outmigration occurs in December and January, while late-fall Chinook salmon fry peak outmigration occurs in April and May. In addition, a secondary peak outmigration of large juvenile spring and fall Chinook salmon also occurs in April and May. We may have underestimated catch during these periods because fry often disperse downstream during high flow events (Healey 1991). However, high flow events only lasted 1 or 2 d, limiting the number of consecutive days catch was estimated. To prevent potential mortality of naturally produced Chinook salmon from overcrowding, we did not operate the LBC trap during hatchery releases of late-fall and fall Chinook salmon; therefore, we had to estimate catch for an additional 5 d in November, January, and April.

Determining whether there are better methods for estimating catch for days the traps are not operational may improve the accuracy of our passage estimates. Currently, average catch for an equal number of days before and after a period of missed sampling is used to estimate catch when the traps are not operated. The accuracy of this method as well as others such as catch per unit volume (CPUV) or effort (CPUE) should be tested to determine whether there is a particular method that is more accurate at estimating catch during high-flow periods and other days the traps are not operated. The CPUE methodology has been used in a few other rotary screw trap studies to estimate passage during periods when traps were not operated (Griffith et al. 2001 and Volkhardt et al. 2005), but comparisons with other methods did not occur.

Recommendation: *Investigate the use of CPUV, CPUE, or other methods to estimate catch for days the trap is not operated.*

Biological Sampling

To effectively estimate passage and describe the biological characteristics of all races of Chinook salmon on Battle Creek, the sampling methods used at the traps must be tested to ensure their applicability and accuracy. Currently, length-at-date criteria for determining run designation (Greene1992) are used on Battle Creek to differentiate runs of juvenile Chinook salmon captured in the traps. However, the criteria were developed for the mainstem Sacramento River, and are not accurate for tributary runs of Chinook salmon. There is significant size overlap between runs, particularly fall and spring Chinook salmon. This discrepancy is important when trying to accurately estimate passage of threatened and endangered Chinook salmon. The size overlap likely resulted in underestimates of spring and overestimates of fall Chinook salmon passage at both traps. A similar overlap occurs between fall and late-fall Chinook salmon in March through May. Considering the overlap between runs, genetic sampling is likely the most accurate method for assigning a run designation. However, it is expensive and will likely only be done on a portion of the total catch, which then requires the results to be extrapolated to the total catch. Also, current genetic techniques for run identification of Central Valley Chinook may need to be verified or refined for application specifically to Battle Creek populations.

Subsampling was used to obtain a representative sample of Chinook salmon for measuring and estimating the length frequency distribution, but fish size or the abundance of uncommon runs may influence the accuracy of this method. Often only a few large fish or those classified as spring and winter Chinook salmon were captured in the traps when fry or other runs were very abundant. Run designation for Chinook salmon included in our subsample was assigned using the length-at-date criteria (Greene 1992). This information was then extrapolated to the unmeasured fish to determine total daily catch for each run. This may have been problematic with larger fish or uncommon runs (spring and winter), because if none were included in the subsample, but they were present in the unmeasured fish, then they were not represented in the final catch totals for that day. However, if they were included in the subsample and then extrapolated to the unmeasured catch, the catch of larger fish and uncommon runs may have been artificially inflated. This likely only occurred at the LBC trap because subsampling rarely occurred at the UBC trap because catch was usually < 250. In mid-February to mid-March 2005, spring and winter Chinook salmon numbers included in the LBC subsample were extrapolated to unmeasured catch, and numbers appear to be significantly higher than seen on the days immediately preceding (Figure 5). Ideally on some days, larger fish or uncommon runs would be under represented in the subsample, and over represented on other days, but whether this occurs has not been determined and should be investigated.

> ***Recommendation**: Develop or utilize methods such as genetics for determining the run designation of Chinook salmon captured in the traps.*

Trap Efficiency and Juvenile Salmonid Passage

Trap efficiency.—Mark-recapture methods are commonly used to estimate trap efficiency, but the results are influenced by many factors, including flow, fish size and species, release time and location, predation, type of mark, etc. In 2004 to 2005, we conducted mark-recapture trials at various flows, but no relationship was found between flow and trap efficiency at the LBC trap, but a weak but significant inverse relationship was found at the UBC trap

(R^2=0.25; P=0.0054). Prior to determining whether there was a relationship with flow, all half-cone trap efficiencies were doubled to make them equivalent to the full-cone trap efficiencies. Trap location as well as other environmental and biological factors may determine how much influence flow has on trap efficiency. Fish size can influence capture efficiency, and ideally we should have conducted separate trials for each species, run, and life stage at various seasons and flows. However, our ability to conduct age, run, and species specific trials was limited by the low abundance of fish available within each category; therefore we used fall Chinook salmon fry and parr as surrogates. The applicability of our estimates to these other groups is questionable, but Roper and Scarnecchia (1996) found that behavioral differences between hatchery and naturally produced Chinook salmon were minimal when traps were operated in higher velocities. They compared trap efficiencies when a 2.43-m (8 ft) diameter trap was rotating an average of 3.05 rotations/min, 2.37 rotations/ min, and 1.40 rotations/min. During the current reporting period, our 1.5-m (5-ft) diameter traps usually rotated an average of 3 to 10 rotations/min, unless there was algae build-up or debris plugging the cone, or during very low flows. It seems possible that at higher velocities the benefits of increased swimming ability found in larger fish may also be smaller. Chapman and Bjornn (1969) and Everest and Chapman (1972) found that fish size was positively correlated with water velocity and depth; therefore, it is possible that trap efficiencies may be higher for larger fish because they are more likely to be found in deeper faster water where our traps are fishing. Release location and time may have also influenced trap efficiencies, but the influences should be similar for all trials because all marked fish were released from the same location and with a few exceptions, all fish were released at dusk or after dark.

The accuracy of our passage estimates was likely affected by our inability to conduct mark-recapture trials at certain times of the year. We only conducted mark-recapture trials from January to May 2005 because insufficient numbers of naturally produced fall Chinook salmon fry and parr were available at other times of the year. The influences on our weekly JPI's were likely small at certain times of the year when catch was low, but, at other times it had a greater influence. For instance, the peak passage of spring Chinook salmon fry normally occurs in December, but to limit our impacts to a federally listed species, we did not conduct mark-recapture trials at that time.

We used two methods for dealing with weeks when mark-recapture trials were not conducted or when recapture were less than seven. First, if the trap efficiency and mean weekly flow of an adjacent week or weeks was similar, we pooled the results of the mark-recapture trials. Otherwise, a season average trap efficiency based on all valid trials was used to estimate passage during weeks when no trials were conducted or when trials from adjacent weeks could not be pooled. The accuracy of our estimates was likely affected by the use of either method; however, the magnitude of the effect depends on the weekly catch at the time it was used and how different the efficiency used to estimate passage (pooled or season average) was from the true trap efficiency. The influence from pooling on the annual JPI estimates at either trap was likely minimal because normally pooling occurs when trap efficiencies and mean weekly flows are similar for the weeks being pooled. Pooling between weeks occurred because recaptures for some or all trials were less than seven. At the LBC trap, pooling between weeks occurred during 3 weeks in late-April to early May, which coincides with the time late-fall Chinook salmon fry and larger spring and fall Chinook salmon outmigrate. However, the pooled trap efficiency for these 3 weeks was fairly similar to the actual weekly trap efficiencies for the weeks being pooled. At the UBC trap pooling occurred during 2 weeks in January, 2 weeks in March, and 3 weeks in late-April to early May, but again the influences on passage estimates was likely minimal.

The use of the full and half-cone season average trap efficiencies likely had a greater influence on weekly and annual passage estimates because we do not know how they compared to the actual trap efficiencies. At the LBC trap, the full-cone season average trap efficiency was used to estimate passage for 6 weeks at the beginning of the migration period (December 2, 2004 to January 10, 2005) and 11 weeks at the end (May 10 to July 27, 2005). The influence on the weekly and annual JPI's was likely greatest at the beginning of the season as weekly catch was higher for fall and spring Chinook salmon. However, fall Chinook salmon weekly catch was significantly higher during periods when mark-recapture trials were conducted. Catch during the first 6 weeks only accounted for about 1.2 % of the total BY04 fall Chinook salmon catch; therefore, the affect on the overall JPI was likely minimal. Using the season average trap efficiency to estimate weekly passage during the first 6 weeks of the spring Chinook salmon outmigration likely had a greater influence on the annual passage estimate because catch during those weeks was about 21% of the total BY04 spring Chinook salmon catch. No spring Chinook salmon were captured when the season average trap efficiency was used at the end of the migration period. The use of the season average trap efficiency likely had a similar influence on late-fall Chinook salmon and rainbow trout/steelhead passage estimates, because 21% of all late-fall Chinook and 24 % of all trout were captured during weeks when the season average trap efficiency was used to estimate passage.

At the UBC trap, the half-cone season average was used for the first 6 weeks of the season, and the full-cone season average trap efficiency was used for the last 10 weeks of the season. The influence on spring and fall Chinook salmon weekly and annual JPI's was likely greatest at the beginning of the season as no spring Chinook salmon and only six fall Chinook salmon were captured when the season average trap efficiency was used at the end of the season. Catch of fall Chinook salmon during the first 6 weeks of the season was 50% of the total season catch; therefore, the affect of using the season average trap efficiency could be potentially significant if it was very different than the actual trap efficiency. The influence on spring Chinook salmon passage estimates could also be significant because catch during the first 6 weeks was 34% of the total catch. Late-fall Chinook salmon passage estimates were not affected by the use of a season average because they were captured during weeks when mark-recapture trials were conducted. However, rainbow trout/steelhead passage estimates were likely also influenced by the use of the season average trap efficiency because 22% of the total catch occurred during periods when the season average trap efficiency was used to estimate passage.

Ideally, daily mark-recapture trials provide the most accurate estimates of trap efficiency (Roper and Scarnecchia 1999), however, they are also very time intensive and expensive. Insufficient numbers of fish were available during most of the season, but when possible two trials were conducted each week. The results of these trials were combined to estimate the weekly trap efficiency. This method has been used by others such as Thedinga et al. (1994), and one of the advantages of this method is some of the variation in flows which may affect trap efficiency during the week are accounted for with a weekly estimate. This method also ensures that sufficient recaptures occur to meet the minimum of seven as was recommended by Steinhorst et al. (2004). In addition, because fish for all trials at each trap were marked the same, it is possible that a few fish from the first trial conducted during the week were captured during the second trial. Results of mark-recapture trials conducted during this report period and previous sampling indicates that most recaptures occur within the first 2 d after release, but occasionally some fish were captured later.

As occurred with our study, mark-recapture release strategies and applications to catch data can vary and the affects on the final estimates needs to be studied further to determine the most effective and efficient method for providing reasonable statistically-sound estimates of trap efficiency. Some studies have developed flow-trap efficiency models to allow the estimation of daily trap efficiencies (Martin et al. 2001). This method appears to be valid, but may not be applicable to all streams. The flow to trap efficiency relationship needs to be sufficiently strong to ensure that estimates of trap efficiency are accurate. Other variables besides flow should also be considered

In future trap operations, mark-recapture trials should be conducted for all weeks when sufficient numbers are available, and release groups should be large enough to ensure a minimum of seven recaptures. This will eliminate the need to pool data from adjacent weeks improving the accuracy of our data. The affects of pooling trials conducted during the same week should also be investigated. The use of hatchery fish is being explored for future mark-recapture trials because it would allow us to conduct trials at times when naturally produced fish are not available or abundant. If hatchery fish are available, paired trials with naturally produced Chinook salmon should be done to test whether behavioral differences exist at all sizes or life-stages. Hatchery fish have been used in some studies, but Roper and Scarnecchia (1996) found that trap efficiencies for hatchery and natural Chinook salmon were different because of differences in behavior. However, they also found that trap efficiencies for hatchery and natural Chinook were similar for a trap operated in relatively high velocities. Differences in behavior may be small when hatchery fry are used as surrogates for naturally produced fry. The use of hatchery fry would allow us to conduct trials during the peak spring Chinook salmon outmigration when flows are more variable.

> ***Recommendation***: *Investigate methods for conducting mark-recapture trials that will improve the accuracy of trap efficiencies such as: (a) conducting robust day and nighttime trials and applying the results to day and nighttime catch, (b) increasing the size of release groups during periods when trap efficiencies are likely to be low (i.e., high flows), (c) marking Chinook salmon so that fish from a particular trial are distinguishable from other trials, and (d) testing the effect of trial frequency on weekly passage estimates.*

> ***Recommendation***: *Investigate the differences in capture efficiency of hatchery and naturally produced Chinook salmon at various life-stages. The ability to use hatchery fish at times when insufficient naturally produced fish are available would reduce the need to use the average season efficiency.*

Juvenile salmonid passage.—Based on non-overlapping 95% confidence intervals, juvenile spring Chinook salmon passage (BY04) at the LBC trap was lower than passage in 2004 (BY03) but higher than passage in 2002 (BY01), passage of BY04 fall Chinook salmon was higher than passage of BY02 and BY03, but lower than passage in BY99, passage of BY05 late-fall Chinook salmon was higher than passage for BY03 and BY04, but not significantly different than all other years, and the combined 2004-2005 age 1+ and yoy rainbow trout/steelhead passage was higher than in 2003-2004, but lower than passage in 1998-1999, 1999-2000, and 2001-2002 (Table 12). A variety of factors may be responsible for the increased or decreased juvenile passage indices, including adult passage, adult survival and spawning success, survival to emergence, high flows, and inaccurate estimates of actual juvenile passage.

The annual JPI for BY04 spring Chinook salmon at the LBC trap was lower than the annual JPI for the BY03, but reasons from the decrease are not readily apparent because of confounding factors. First, the amount of fork length overlap that occurs when using the length-at-date criteria to assign a run designation likely differs between years. The use of genetic analyses to determine the amount and variability of overlap may improve the reliability of our estimates as long as the methods are capable of accurately differentiating runs of Chinook salmon. Second, no estimates of adult spring Chinook salmon escapement were made below the barrier weir; and although it is possible that some spawned downstream there would be no way to distinguish juvenile spring Chinook salmon produced above the barrier weir from those produced below the barrier weir. Ideally all adult spring-run Chinook salmon were passed upstream of the barrier weir, and juvenile passage is likely better estimated with the UBC trap.

The increase in BY04 fall Chinook salmon is not related to an increase in adult escapement because only 23,861 adults were estimated to be downstream of the barrier weir in 2004 compared to about 64,764 in 2003 (CDFG 2007). It is possible that the increase is related to increased adult survival and spawning success, but since adult spawning is not monitored downstream of the barrier weir this cannot be verified. High survival to emergence may also account for the increase in juvenile passage as temperatures during incubation were within the range for maximum embryo survival (5 to 13^{o}C; Vogel and Marine 1991), and the only high flow event that may have resulted in some redd scouring occurred on January 26, 2005 when peak flow at the USGS gauging station near the barrier weir was 85 m^3/s (3,000cfs; Figures 17 and 18).

The release of hatchery fall Chinook salmon in April likely influenced the accuracy of our fall Chinook salmon weekly and annual JPI's. No hatchery fall Chinook salmon were marked in 2005; therefore, we were not able to estimate the proportion captured in the LBC trap. To prevent overestimating the daily catch of naturally produced Chinook salmon of similar size, we did not include salmon >59 mm in our daily catch from April 19 to late-June which resulted in an underestimate of juvenile fall and spring Chinook salmon passage during this period. Excluding these fish likely also affected our life-stage composition for these runs by underestimating catch of parr, silvery parr, and smolt.

The annual JPI estimate for BY05 late-fall Chinook salmon is much higher than the two previous brood years, but reasons for the increase are not readily apparent because of limited information. As seen with spring Chinook salmon, the length-at-date criteria used to assign run designation does not appear to be accurate because there was overlap with fall Chinook salmon in March through May. In addition, in-river adult escapement estimates were not available for late-fall Chinook salmon; therefore, if an increase in adult escapement occurred, it was not readily apparent. The only escapement information available is the number of late-fall Chinook salmon taken into the hatchery (N=6,435), which was the second highest on record (CDFG 2007). If the numbers taken into the hatchery are proportional to the number below the barrier weir, it is possible that late-fall Chinook salmon adult escapement below the weir increased in 2005. However, the increase may only be applicable to hatchery late-fall and not naturally produced late-fall, because escapement of naturally produced late-fall Chinook salmon above the barrier weir was extremely low compared to previous years (N=23; Newton et al. 2007

Rainbow trout/steelhead annual JPI estimates at the LBC trap were higher than 2004, but still lower than estimates in 1999, 2000, and 2002. No estimates of adult rainbow trout/steelhead escapement or spawning success were made below the barrier weir; and although it is possible that some spawned downstream there would be no way to distinguish juveniles produced above the barrier weir from those produced below the barrier weir. The UBC trap is likely better used to correlate passage of naturally-produced rainbow trout/steelhead with adult escapement, spawning success, and environmental factors in Battle Creek.

The UBC trap monitors juvenile passage from adult spring, fall, and late-fall Chinook salmon and rainbow trout/steelhead escapement above the barrier weir. In 2005, the spring Chinook salmon annual JPI for BY04 (N=3,253) at the UBC trap was significantly lower than

BY98, BY99, and BY03, but higher than BY01 and BY02, the BY04 fall Chinook salmon annual JPI (N=26,763) was higher than the BY01 and BY02 passage estimates, but lower than BY98, BY99, and BY03, the BY05 late-fall Chinook salmon annual JPI (N=147) was significantly lower than all previous estimates, and the combined age 1+ and yoy rainbow trout/steelhead passage estimate (N=5,975) was higher than the 2004 estimate, but lower than all other available passage estimates (Table 13).

Adult passage, spawning success, survival to emergence, flows and temperatures likely had some influence on the patterns observed in juvenile passage at the UBC trap. From March 2 to August 1, 2004 Alston et al. (2007) estimated that 2 clipped and 90 unclipped Chinook salmon were passed through the barrier weir fish ladder. This estimate does not include Chinook salmon that were passed upstream by CNFH prior to March 2; however, based on run-timing, those fish were likely parents of BY04 late-fall Chinook salmon which were summarized in the 2003-2004 report (Whitton et al. 2007c). Alston et al. (2007) used a variety of information including migration timing, coded-wire tag recoveries, and genetic analyses to estimate that of the 90 unclipped Chinook salmon passed, 70 were spring-run and 20 were fall-run Chinook salmon. The two clipped Chinook salmon were likely BY04 hatchery late-fall. An additional 19 Chinook salmon were observed jumping or swimming over the barrier weir between August 1 and November 30, 2004. Based on run-timing, these fish were likely fall-run. In 2004, Alston et al. (2007) estimated a spring Chinook salmon spawning population of 63 based on stream survey redd counts (34 redds). Unclipped Chinook passage upstream of the barrier weir in 2004 (N=90) was less than half of unclipped passage in 2003 (N=221), which may account for the decrease observed in both spring and fall Chinook salmon passage estimates. The increase of spring Chinook JPI for BY04 relative to BY01 and BY02 was likely a result of improved flows and water temperatures (Figures 17 and 18). Interim flows (i.e., minimum instream flows) of at least 0.85 m^3/s (30 cfs) were provided in both the north and south forks of Battle Creek in 2004 as well as 1998 through 2000. But, in 2001 and 2002, interim flows were greatly reduced in the South Fork Battle Creek for most or all of the holding and spawning period of spring Chinook; down to about 0.14 m^3/s (5 cfs) in 2001 and 0.28 m^3/s (10 cfs) in 2002 (Whitton et al. 2007b). This led to high water temperatures and reduced habitat.

The proportion of juvenile spring to fall Chinook salmon passage was higher for BY04 than in previous years. For BY04, 11.5% of the combined spring and fall Chinook salmon juvenile passage was spring-run, while in previous years, spring-run were ≤7.4%. In 2004, the barrier weir fish ladder was closed August 1, instead of the end of August as was done from 2000-2003, to prevent adult hatchery fall Chinook from entering upper Battle Creek. Closing the fish ladder earlier in 2004 may have increased the relative proportion of spring Chinook. Also, interannual variation in the size overlap of spring and fall-run juveniles may influence the relative proportions of JPIs when using the length-at-date criteria to assign a run-designation. Genetic analyses of tissue samples collected during these periods of overlap could be useful for determining the amount of overlap that occurs and how variable it is as long as the available current methods are capable of accurately differentiating runs of Chinook salmon. Also, it may be useful to combine annual spring and fall-run JPI's for interannual comparisons or when investigating possible correlations with adult escapement estimates and environmental conditions during the holding and spawning periods.

The BY05 late-fall Chinook salmon annual JPI of 147 at the UBC trap was significantly lower than annual JPI's for all other brood years. Reduced adult passage is likely the primary reason for the decrease because temperatures and flows were favorable during the holding, spawning, and incubation periods. From October 2004 to February 2005, hatchery staff only passed 23 late-fall Chinook salmon above the barrier weir, and no additional late-fall were passed upstream while the barrier weir trap was operated (Newton et al. 2007). The late-fall adult escapement in 2005 was almost half of the previous low escapement of 42 in 2004. In addition, there were two high flow events in May that required us to estimate daily catch for 4 d; therefore, it is possible that we underestimated catch on those days. However, in previous years, peak passage of late-fall Chinook salmon fry usually occurred in April. There appears to be a 4-year decreasing trend in late-fall Chinook salmon adult escapement above the barrier weir and a similar decrease in juvenile passage estimates at the UBC trap (Figure 19). Reasons for this apparent decrease should be investigated.

The combined 2005 rainbow trout/steelhead annual JPI estimate of 5,934 for the UBC trap was significantly higher than the estimate in 2004, but lower than in 1999, 2000, and 2002. In 2005, hatchery staff passed 270 rainbow trout/steelhead upstream of the barrier weir, and an additional 74 were passed upstream while the barrier weir trap was operated (Newton et al. 2007). Adult passage was lower than observed in 2004, but juvenile passage was significantly higher, suggesting that spawning success and/or survival to emergence was higher in 2005. In 2004, there were some potential redd scouring flows that may have contributed to the low juvenile to adult production, but in 2005, there were no redd scouring events prior to juvenile emergence. The only flow event that could have had an impact occurred in late-December. Peak flow was 73.6 m^3/s (2,600 cfs) with 4 days over 28.3 m^3/s (1,000 cfs). There was one additional flow event in early January that had a peak flow of 49.6 m^3/s (1,750 cfs), which likely did not cause redd scouring.

Recommendation: *Investigate the relationship between flows and redd scour and the impact on juvenile passage.*

Recommendation: *Investigate potential reasons for the apparent decline in naturally-produced late-fall Chinook salmon escapement above the barrier weir.*

Acknowledgements

We would like to thank the Red Bluff Fish and Wildlife Office staff who also worked on this project: Naseem Alston, Felipe Carrillo, Joe Chigbrow, David Colby, Jim Earley, Jimmy Faukner, Robert Feamster, Shea Gaither, Andy Hill, Ethan Jankowsky, Matt Johnson, Tim Loux, Ed Martin, Matt McCormack, Phil Moeller, Laurie Stafford, Jonathan Sutliff, Brandon Thompson, Paul Walfoort, Lael Will and Kara Yetishevsky. We thank the Coleman National Fish Hatchery staff, especially Scott Hamelberg and Mike Keeler, for accommodating our program at the Coleman National Fish Hatchery.

References

Alston, N. O., J. M. Newton, and M. R. Brown. 2007. Monitoring adult Chinook salmon, rainbow trout, and steelhead in Battle Creek, California, from November 2003 through November 2004. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Bailey, N. T. J. 1951. On estimating the size of mobile populations from capture-recapture data. Biometrika 38:293-306.

Buckland, S. T., and P. H. Garwaite. Quantifying precision of mark-recapture estimates using the bootstrap and related methods. Biometrics 47: 255-268.

CDFG (California Department of Fish and Game). 2007. GrandTab (Updated: February 4, 2007). Native Anadromous Fish and Watershed Branch. Available: www.delta.dfg.ca.gov/AFRP/documents/GrandTab020407.xls. (June 2007).

CVPIA (Central Valley Project Improvement Act). 1997. CVPIA comprehensive assessment and monitoring program: standard protocol for rotary screw trapping. Central Valley Fish and Wildlife Restoration Program Office, Sacramento, CA.

Carlson, S. R., L. G. Coggins Jr., and C. O. Swanton. 1998. A simple stratified design for mark-recapture estimation of salmon smolt abundance. Alaska Fishery Research Bulletin 5(2):88-102.

Chapman, D. W., and T. C. Bjornn. 1969. Distribution of salmonids in streams, with special reference to food and feeding. Pages 153-176 *in* T. G. Northcote, editor. Symposium on Salmon and Trout in Streams. H.R. MacMillan Lectures in Fisheries. Institute of Fisheries, University of British Columbia, Vancouver, BC. 388p.

Efron, B., and R. Tibshirani. 1986. Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. Statistical Science 1:54-77.

Everest, F. H. and D. W. Chapman. 1972. Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. Journal of the Fisheries Research Board of Canada 29:91-100.

Greene, S. 1992. Estimated winter-run Chinook salmon salvage at the state water project and Central Valley Project delta pumping facilities. Memorandum dated 8 May 1992, from Sheila Greene, State of California Department of Water Resources to Randall Brown, California Department of Water Resources. 3 pp., plus 15 pp. tables.

Griffith, J., R. Roger, and J. Drotts. 2001. 2001 Stillaguamish River smolt trapping project. Stillaguamish Tribe of Indians, Arlington, WA.

Healey, M. C. 1991. Life history of Chinook salmon. Pages 311 - 393 *in* C. Groot and L. Margolis, editors. Pacific salmon life histories. UBC Press, University of British Columbia, Vancouver, B.C, Canada.

Jones & Stokes. 2004. Battle Creek Salmon and Steelhead Restoration Project action specific implementation plan. Draft. April. (J&S 03-035.) Sacramento, CA.

Martin, C. D., P. D. Gaines and R. R. Johnson. 2001. Estimating the abundance of Sacramento River juvenile winter Chinook salmon with comparisons to adult escapement. Red Bluff Research Pumping Plant Report Series, Volume 5. U. S. Fish and Wildlife Service, Red Bluff, CA.

Moyle, P. B. 2002. Inland Fishes of California. University of California Press, Berkeley, California.

Newton, J. M., N. O. Alston, and M. R. Brown. 2007. Monitoring adult Chinook salmon, rainbow trout, and steelhead in Battle Creek, California, from November 2004 through November 2005. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Roper, B. and D. Scarnecchia. 1996. A comparison of trap efficiencies for wild and hatchery age-0 Chinook salmon. North American Journal of Fisheries Management 16:214-217.

Roper, B. and D. Scarnecchia. 1999. Emigration of age-0 Chinook salmon (Oncorhychus tshawytscha) smolts from the upper South Umpqua River basin, Oregon, USA. Canadian Journal of Fisheries and Aquatic Sciences 56: 939-946.

Steinhorst, K., Y. Wu, B. Dennis, and P. Kline. 2004. Confidence intervals for fish outmigration estimates using stratified trap efficiency methods. Journal of Agricultural, Biological, and Environmental Statistics 9: 284-299.

Thedinga, J. F., M. L. Murphy, S. W. Johnson, J. M. Lorenz, and K V. Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management 14:837-851.

USFWS (U.S. Fish and Wildlife Service). 1997. Revised Draft Restoration Plan for the Anadromous Fish and Restoration Program. A plan to increase natural production of anadromous fish in the Central Valley of California. Prepared for the U.S. Fish and Wildlife Service under the direction of the Anadromous Fish and Restoration Program Core Group. May 30, 1997.

USFWS (U.S. Fish and Wildlife Service). 2001. Biological assessment of artificial propagation at Coleman National Fish Hatchery and Livingston Stone National Fish Hatchery: program description and incidental take of Chinook salmon and steelhead trout. Red Bluff, CA.

USFWS (U.S. Fish and Wildlife Service) and USBR (U.S. Bureau of Reclamation). 2002. Comprehensive Assessment and Monitoring Program (CAMP) Annual Report 2000. Prepared by CH2M HILL, Sacramento, California.

Vogel, D. A., and K. R. Marine. 1991. Guide to upper Sacramento River Chinook salmon life history. U.S. Bureau of Reclamation Central Valley Project. CH2M Hill, Redding, CA.

Volkhardt, P.T., L. Fleischer, T. Miller, and S. Schonning. 2005. 2004 juvenile salmonid production evaluation report: Green River, Wenatchee River, and Cedar Creek. Washington Department of Fish and Wildlife –Fish Program FPA05-13.

Ward, M. B., and W. M. Kier. 1999. Battle Creek salmon and steelhead restoration plan. Report by Kier Associates to Battle Creek Working Group.

Whitton, K. S., J. M. Newton, D. J. Colby, and M. R. Brown. 2006. Juvenile salmonid monitoring in Battle Creek, California, from September 1998 to February 2001. USFWS Data Summary Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, CA.

Whitton, K. S., J. M. Newton, and M. R. Brown. 2007a. Juvenile salmonid monitoring in Battle Creek, California, from July 2001 through September 2002. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, CA.

Whitton, K. S., J. M. Newton, and M. R. Brown. 2007b. Juvenile salmonid monitoring in Battle Creek, California, from October 2002 through September 2003. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, CA.

Whitton, K. S., J. M. Newton, and M. R. Brown. 2007c. Juvenile salmonid monitoring in Battle Creek, California, from October 2003 through September 2004. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, CA.

Tables

Table 1. Life-stage summary of spring, fall, late-fall, spring and winter Chinook salmon and rainbow trout/steelhead captured at the Lower and Upper Battle Creek rotary screw traps from October 1, 2004 through September 30, 2005.

	Spring Chinook		Fall Chinook		Late-Fall Chinook		Winter Chinook		Rainbow	
Life Stage	#	%	#	%			#	%	#	%
					Lower Battle Creek (LBC)					
Yolk Sac Fry	0	0	2,415	12.5	68	2.5	0	0	6	4.3
Fry	88	22.5	14,630	76.2	2,550	94.3	0	0	73	52.9
Parr	29	7.4	1,491	7.8	85	3.1	0	0	44	31.9
Silvery Parr	164	41.8	632	3.3	2	0.1	13	52.0	7	5.1
Smolt	111	28.3	36	0.2	0	0	12	48.0	8	5.8
Totals	*392*	*100*	*19,204*	*100*	*2,705*	*100*	*25*	*100*	*138*	*100*
					Upper Battle Creek (UBC)					
Yolk Sac Fry	2	1.7	11	1.3	0	0	0	0	0	0
Fry	42	34.7	822	95.0	5	83.3	0	0	44	19.6
Parr	2	1.7	7	0.8	1	16.7	0	0	140	62.5
Silvery Parr	21	17.3	11	1.3	0	0	0	0	28	12.5
Smolt	54	44.6	14	1.6	0	0	4	100	12	5.4
Totals	*121*	*100*	*865*	*100*	*6*	*100*	*4*	*100*	*224*	*100*

Table 2. Summary of the mark-recapture trials conducted at the Lower Battle Creek rotary screw trap from October 1, 2004 to September 30, 2005. Shaded rows indicate weeks where mark-recapture data were pooled for analysis. Trials conducted during the same week were pooled to calculate the average weekly trap efficiency, and when recaptures were <7 mark-recapture data were pooled with data from adjacent weeks if flows and trap efficiencies were similar, otherwise the season average trap efficiency (half-cone: E= 0.032; full-cone: E=0.063) was used to calculate weekly passage. Trials highlighted in **bold** were not used, and trials in *italicized* font were conducted while the trap was in ½ cone status.

Release Date	Time of Release	Number Released	Recaptures	Efficiency[a]	Pooled /Season Avg. Efficiency	Weekly Mean Flow, m^3/s (cfs)
01/11/05	02:57	91	8	0.098	0.073	10.95 (384)
01/14/05	02:42	142	8	0.063	0.073	10.9 (384)
01/21/05	19:33	388	8	0.023	---	8.9 (313)
01/25/05	19:10	390	10	0.028	---	16.3 (577)
01/28/05	**18:22**	**406**	**1**	---	---	16.3 (577)
02/01/05	18:45	383	23	0.063	0.070	9.5 (336)
02/04/05	19:20	506	38	0.077	0.070	9.5 (336)
02/08/05	17:54	409	39	0.098	0.101	9.6 (340)
02/11/05 [b]	19:42	418	22 (44)	0.055 (0.107)	0.101	9.6 (340)
02/15/05	19:27	388	17	0.046	0.047	12.1 (427)
02/18/05	19:37	401	19	0.050	0.047	12.1 (427)
02/22/05	19:00	439	14	0.034	0.036	11.8 (418)
02/25/05	19:15	398	15	0.040	0.036	11.8 (418)
03/01/05	18:11	411	8	0.022	0.022	12.8 (454)
03/04/05	15:57	328	7	0.024	0.022	12.8 (454)
03/08/05	19:45	391	17	0.046	0.045	10.8 (383)
03/11/05	19:25	422	19	0.047	0.045	10.8 (383)
03/15/05	18:11	218	13	0.064	0.042	10.5 (370)
03/18/05	16:44	137	1	0.014	0.042	10.5 (370)
03/22/05	18:47	120	5	0.050	0.038	13.6 (479)
03/25/05	20:56	113	3	0.035	0.038	13.6 (479)
04/01/05	18:25	292	14	0.051	---	12.5 (442)
04/05/05	18:42	136	9	0.073	---	14.2 (501)
04/12/05	18:10	171	11	0.070	---	12.0 (424)
04/19/05	19:41	90	3	0.044	0.039	11.8 (416)
04/26/05	18:45	71	3	0.056	0.039	12.1 (427)
05/06/05	15:37	118	4	0.042	0.039	21.4 (757)
05/13/05	**17:36**	**66**	**0**	**---**	0.063	22.7 (803)

[a] Bailey's Efficiency was calculated by: $\hat{E} = \frac{r+1}{m+1}$, where r = recaptures and m = number of marked fish released.

[b] To allow pooling, recaptures were doubled to make this half-cone trial equivalent to the full-cone trial conducted during the same week. Full-cone values are in parenthesis. Catch was doubled on days the trap operated at half-cone status.

Table 3. Summary of the mark-recapture trials conducted at the Upper Battle Creek rotary screw trap from October 1, 2004 to September 30, 2005. Shaded rows indicate weeks where mark-recapture data were pooled for analysis. Trials conducted during the same week were pooled to calculate the average weekly trap efficiency, and when recaptures were <7 mark-recapture data from adjacent weeks were pooled if flows and trap efficiencies were similar, otherwise the season average trap efficiency (half-cone: E=0.032; full cone: E=0.065) was used to calculate weekly passage. Trials highlighted in **bold** were not used, and trials in *italicized* font were conducted while the trap was in ½ cone status.

Release Date	Release Time	Number Released	Recaptures	Efficiency[a]	Pooled /Season Avg. Efficiency	Weekly Mean Flow, m^3/s (cfs)
01/04/05	*21:00*	*105*	*4*	*0.047*	*0.042*	*14.5 (512)*
01/11/05	***01:30***	***91***	***1***	---	---	*10.9 (384)*
01/14/05	*02:27*	*130*	*5*	*0.046*	*0.042*	*10.9 (384)*
01/21/05	*19:50*	*380*	*16*	*0.045*	---	*8.9 (313)*
01/24/05	*19:29*	*388*	*6*	*0.018*	*0.023*	*16.3 (577)*
01/28/05	*18:35*	*403*	*11*	*0.030*	*0.023*	*16.3 (577)*
02/01/05	*19:05*	*413*	*11*	*0.029*	*0.029*	*9.5 (336)*
02/04/05	*19:38*	*448*	*14*	*0.033*	*0.029*	*9.5 (336)*
02/08/05[b]	*17:39*	*399*	*14 (28)*	*0.038 (0.073)*	*0.060*	*9.6 (340)*
02/11/05	19:58	415	20	0.050	0.060	9.6 (340)
02/15/05	19:38	440	34	0.079	0.078	12.1 (427)
02/18/05	19:50	408	31	0.078	0.078	12.1 (427)
02/22/05	19:21	431	34	0.081	0.083	11.8 (418)
02/25/05	19:40	408	35	0.088	0.083	11.8 (418)
03/01/05	17:52	403	19	0.050	0.044	12.8 (454)
03/04/05	18:46	373	14	0.040	0.044	12.8 (454)
03/08/05	20:05	525	41	0.080	0.076	10.8 (383)
03/11/05	19:50	387	27	0.072	0.076	10.8 (383)
03/15/05	18:37	318	21	0.069	---	10.5 (370)
03/22/05	18:22	114	4	0.043	0.037	13.6 (479)
03/25/05	20:31	111	2	0.027	0.037	13.6 (479)
04/01/05	18:10	237	9	0.042	0.037	12.5 (442)
04/05/05	18:57	152	4	0.033	0.071	14.2 (501)
04/08/05	18:45	198	20	0.106	0.071	14.2 (501)
04/12/05	19:24	171	12	0.076	0.047	12.0 (424)
04/15/05	19:11	383	13	0.036	0.047	12.0 (424)
04/19/05	19:56	89	7	0.089	---	11.8 (416)
04/29/05	17:27	100	2	0.030	0.029	12.1 (427)
05/06/05	15:46	113	4	0.044	0.029	21.4 (757)
05/13/05	16:54	65	1	0.030	0.029	22.7 (803)

[a] Bailey's Efficiency is calculated by: $\hat{E} = \frac{r+1}{m+1}$, where r = recaptures and m = marks.

[b] To allow pooling, recaptures were doubled to make this half-cone trial equivalent to the full-cone trial conducted during the same week. Full-cone values are in parenthesis. Catch was doubled on days the trap operated at half-cone status.

Table 4. Weekly summary of brood year 2004 juvenile spring Chinook salmon passage estimates for the Lower Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI).

Week	Efficiency (E)	Catch[b]	Estimated Passage (N)	SE[c]	90% Confidence Interval[c]		95% Confidence Interval[c]	
					Lower CI	Upper CI	Lower CI	Upper CI
12/07/04	0.063[a]	6	96	18	72	128	67	141
12/14/04	0.063[a]	60	955	176	720	1,283	703	1,342
12/21/04	0.063[a]	21	334	58	252	431	246	449
12/28/04	0.063[a]	2	32	6	24	43	23	45
02/22/05	0.036	6	168	29	126	219	123	239
03/08/05	0.045	7	154	26	119	204	114	211
03/15/05	0.042	8	190	50	129	285	119	316
03/22/05	0.038	108	2,808	1,007	1,685	4,212	1,580	5,054
03/29/05	0.051	73	1,426	374	972	2,139	891	2,377
04/05/05	0.073	91	1,247	465	779	2,078	693	2,493
04/12/05	0.070	40	573	167	362	860	344	983
Totals	**---**	***422***	***7,983***	***1,189***	***6,434***	***10,015***	***6,256***	***10,884***

[a] The 2004 to 2005 full-cone season average efficiency, was based on valid full-cone and half-cone trials conducted January 11, 2005 through May 13, 2005. The full-cone season average was applied during weeks when no mark-recapture trials were conducted, and the trap was operating at full-cone.
[b] Daily catch was estimated for days the trap was not fishing.
[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.

Table 5. Weekly summary of brood year 2004 juvenile fall Chinook salmon passage estimates for the Lower Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Shaded rows indicate adjacent weeks where the results of mark-recapture trials were pooled to calculate passage.

Week	Efficiency (E)	Catch[b]	Estimated Passage (N)	SE[c]	90% Confidence Interval[c]		95% Confidence Interval[c]	
					Lower CI	Upper CI	Lower CI	Upper CI
11/30/04	0.063[a]	1	16	3	12	21	11	22
12/07/04	0.063[a]	50	796	147	600	1,070	559	1,118
12/14/04	0.063[a]	276	4,394	803	3,312	5,904	3,158	6,172
12/21/04	0.063[a]	454	7,227	1,291	5,448	9,307	5,195	10,153
12/28/04	0.063[a]	1,073	17,082	3,082	12,876	21,997	12,569	25,139
01/04/05	0.063[a]	1,023	16,286	2,961	12,583	21,883	11,705	23,967
01/11/05	0.073	2,442	33,613	7,689	23,810	47,619	21,978	51,948
01/18/05	0.023	3,662	158,280	57,532	94,968	284,903	83,795	284,904
01/25/05	0.028	21,495	764,050	241,127	494,385	1,200,649	466,919	1,400,758
02/01/05	0.070	20,242	290,571	35,553	237,044	346,450	228,043	360,308
02/08/05	0.101	100,970	995,276	108,231	844,476	1,177,509	819,639	1,247,808
02/15/05	0.047	58,827	1,256,036	221,992	948,435	1,659,762	911,242	1,787,436
02/22/05	0.036	12,297	343,496	63,714	257,622	468,404	245,354	490,709
03/01/05	0.022	6,706	310,153	84,165	206,768	451,131	198,498	496,244
03/08/05	0.045	2,965	65,230	10,739	50,281	83,224	48,270	89,389
03/15/05	0.042	631	14,976	4,032	9,767	22,464	9,360	24,960
03/22/05	0.038	735	19,110	6,874	11,466	34,398	10,749	34,398
03/29/05	0.051	931	18,186	5,231	11,860	27,278	11,366	30,309
04/05/05	0.073	1,121	15,358	6,518	9,599	25,596	9,034	30,715
04/12/05	0.070	736	10,549	3,548	6,663	15,824	6,330	18,085
04/19/05	0.039	38	967	307	626	1,520	560	1,773
04/26/05	0.039	51	1,298	414	840	2.040	752	2,380
05/03/05	0.039	80	2,036	669	1,318	3,200	1,244	3,733
05/10/05	0.063[a]	132	2,102	378	1,584	2,824	1,510	2,952
05/17/05	0.063[a]	36	573	107	432	770	412	843
05/24/05	0.063[a]	50	796	149	600	1,070	572	1,171
05/31/05	0.063[a]	32	510	90	384	656	366	716
06/07/05	0.063[a]	1	16	3	12	21	11	22

Table 5. (Cont.)

06/14/05	0.063[a]	2	32	6	25	43	23	47
06/21/05	0.063[a]	2	32	6	25	43	23	47
06/28/05	0.063[a]	3	48	9	36	64	34	67
07/12/05	0.063[a]	1	16	3	12	21	11	22
07/26/05	0.063[a]	1	16	3	12	21	11	22
Totals	---	***237,066***	***4,349,127***	***368,199***	***3,822,231***	***4,993,838***	***3,724,470***	***5,174,112***

[a] The 2004 to 2005 full-cone season average efficiency, was based on valid full-cone and half-cone trials conducted January 11, 2005 through May 13, 2005. The full-cone season average was applied during weeks when no mark-recapture trials were conducted, and the trap was operating at full-cone.

[b] Daily catch was estimated for days the trap was not fishing.

[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.

Table 6. Weekly summary of brood year 2005 juvenile late-fall Chinook salmon passage estimates for the Lower Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Shaded rows indicate adjacent weeks where the results of mark-recapture trials were pooled to calculate passage. Only weeks in which late-fall Chinook salmon were captured are included. However, several weeks outside of the reporting dates (October 1 to December 24, 2005) are included to allow estimation of the total annual JPI for brood year 2005 (below dashed line).

Week	Efficiency (E)	Catch[b]	Estimated Passage (N)	SE[c]	90% Confidence Interval[c]		95% Confidence Interval[c]	
					Lower CI	Upper CI	Lower CI	Upper CI
03/29/05	0.051	72	1,406	378	959	2,110	879	2,344
04/05/05	0.073	343	4,699	1,474	2,764	6,713	2,611	7,832
04/12/05	0.070	515	7,382	2,252	4,662	11,073	4,429	12,654
04/19/05	0.039	176	4,480	1,504	2,738	7,040	2,594	8,213
04/26/05	0.039	509	12,956	4,261	7,918	20,360	7,501	23,753
05/03/05	0.039	1,059	26,956	9,923	17,442	42,360	15,606	49,420
05/10/05	0.063[a]	358	5,701	1,028	4,296	7,658	4,096	8,006
05/17/05	0.063[a]	84	1,338	239	1,008	1,797	961	1,879
05/24/05	0.063[a]	113	1,799	326	1,356	2,417	1,293	2,527
05/31/05	0.063[a]	74	1,178	216	888	1,517	847	1,655
06/07/05	0.063[a]	62	987	176	744	1,326	726	1,387
06/14/05	0.063[a]	10	159	29	123	214	114	234
06/21/05	0.063[a]	5	80	14	60	103	57	112
06/28/05	0.063[a]	2	32	6	25	43	23	47
07/05/05	0.063[a]	1	16	3	12	21	11	22
10/1 to 12/31/05[d]	---	0	--	---	---	---	---	---
Totals	***---***	***3,383***	***69,169***	***11,179***	***55,279***	***88,536***	***53,440***	***92,898***

[a] The 2004 to 2005 full-cone season average efficiency, was based on valid full-cone and half-cone trials conducted January 11, 2005 through May 13, 2005. The full-cone season average was applied during weeks when the trap was operating at full-cone but no mark-recapture trials were conducted.

[b] Daily catch was estimated for days the trap was not fishing.

[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.

[d] No additional late-fall Chinook salmon were captured during this period; however, the LBC trap was not operated from October 1 to December 7, 2005.

Table 7. Weekly summary of rainbow trout/steelhead passage estimates for the Lower Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Weekly estimates listed above the dotted line are for trout from previous brood years (age 1+). Weekly estimates below the line are for brood year 2005 trout captured during the reporting period. Shaded rows indicate adjacent weeks where the results of mark-recapture trials were pooled to calculate passage. Weeks with no catch are not included.

Week	Efficiency (E)	Catch[b]	Estimated Passage (N)	SE[c]	90% Confidence Interval[c] Lower CI	90% Confidence Interval[c] Upper CI	95% Confidence Interval[c] Lower CI	95% Confidence Interval[c] Upper CI
Previous Brood Years (Age 1+)								
11/30/04	0.063[a]	1	16	3	12	21	11	22
12/07/04	0.063[a]	1	16	3	12	21	11	22
12/14/04	0.063[a]	1	16	3	12	21	11	22
01/11/05	0.073	1	14	3	10	21	9	23
01/25/05	0.028	1	36	11	22	56	21	65
02/01/05	0.070	1	14	2	12	18	11	19
04/05/05	0.073	6	82	31	51	137	48	164
04/12/05	0.070	2	29	13	18	43	17	49
04/26/05	0.039	2	51	18	31	80	29	93
05/03/05	0.039	2	51	18	31	80	29	93
05/17/05	0.063[a]	1	16	3	12	21	11	22
06/21/05	0.063[a]	1	16	3	12	21	11	22
Totals		***20***	***357***	***51***	***291***	***447***	***284***	***469***
Brood Year 2005 (YOY)								
02/22/05	0.036	1	28	5	21	36	20	40
03/01/05	0.022	38	1,758	484	1,223	2,556	1,125	2,812
03/08/05	0.045	12	264	42	204	337	195	362
03/15/05	0.042	11	261	81	170	392	163	435
03/22/05	0.038	3	78	26	47	117	44	140
03/29/05	0.051	8	156	43	107	234	102	260
04/05/05	0.073	12	164	58	103	274	97	328
04/12/05	0.070	4	57	20	36	86	39	98
04/19/05	0.039	3	76	24	49	120	47	140
04/26/05	0.039	1	25	9	16	40	15	47

Table 7. (Contin.)

05/03/05	0.039	3	76	23	47	120	44	140
05/10/05	0.063[a]	16	255	46	192	342	183	358
05/17/05	0.063[a]	6	96	17	72	128	69	141
05/24/05	0.063[a]	3	48	8	36	62	35	67
05/31/05	0.063[a]	5	80	14	60	103	57	112
Totals	**---**	***126***	***3,422***	***500***	***2,809***	***4,289***	***2,739***	***4,682***

[a] The 2004 to 2005 full-cone season average efficiency, was based on valid full-cone and half-cone trials conducted January 11, 2005 through May 13, 2005. The full-cone season average was applied during weeks when no mark-recapture trials were conducted, and the trap was operating at full-cone.
[b] Daily catch was estimated for days the trap was not fishing.
[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.

Table 8. Weekly summary of brood year 2004 juvenile spring Chinook salmon passage estimates for the Upper Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Shaded rows indicate adjacent weeks where the results of mark-recapture trials were pooled to calculate passage. Only weeks in which spring Chinook salmon were captured are included.

Week	Efficiency (E)	Catch[b]	Estimated Passage (N)	SE[c]	90% Confidence Interval[c]		95% Confidence Interval[c]	
					Lower CI	Upper CI	Lower CI	Upper CI
11/16/04	0.032[a]	2	62	16	43	92	40	101
12/07/04	0.032[a]	18	563	147	383	830	356	995
12/14/04	0.032[a]	24	750	180	531	1,106	492	1,207
02/08/05	0.060	2	33	5	27	42	26	44
03/01/05	0.044	1	23	4	18	30	17	32
03/08/05	0.076	4	53	6	43	64	42	66
03/15/05	0.069	3	44	9	31	60	30	64
03/22/05	0.037	9	240	64	160	349	154	384
03/29/05	0.042	19	452	172	283	754	266	904
04/05/05	0.071	13	183	37	130	254	127	268
04/12/05	0.047	17	363	76	262	497	248	555
04/19/05	0.089	6	68	27	39	108	36	135
04/26/05	0.029	5	174	76	100	279	93	349
05/03/05	0.029	2	70	30	40	112	37	140
05/10/05	0.029	3	105	53	60	167	56	209
05/17/05	0.065[d]	1	15	3	12	20	11	21
Totals	---	***129***	***3,198***	***336***	***2,725***	***3,817***	***2,684***	***3,923***

[a] Half-cone season average efficiency was calculated using all valid un-pooled and pooled trials conducted January 4 to May 13, 2005. The half-cone season average was applied during weeks when no mark-recapture trials were conducted, and the trap was operating at half-cone.
[b] Daily catch was estimated for days the trap was not fishing.
[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.
[d] Full-cone season average efficiency was calculated using all valid un-pooled and pooled trials conducted January 4 to May 13, 2005. The full-cone season average was applied during weeks when no mark-recapture trials were conducted, and the trap was operating at full-cone.

Table 9. Weekly summary of brood year 2004 juvenile fall Chinook salmon passage estimates for the Upper Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Shaded rows indicate adjacent weeks where the results of mark-recapture trials were pooled to calculate passage.

Week	Efficiency (E)	Catch[b]	Estimated Passage (N)	SE[c]	90% Confidence Interval[c] Lower CI	90% Confidence Interval[c] Upper CI	95% Confidence Interval[c] Lower CI	95% Confidence Interval[c] Upper CI
12/07/04	0.032[a]	37	1,156	292	787	1,705	758	1,860
12/14/04	0.032[a]	118	3,688	921	2,510	5,438	2,417	5,932
12/21/04	0.032[a]	109	3,406	884	2,318	5,023	2,232	5,480
12/28/04	0.032[a]	218	6,813	1,664	4,637	10,046	4,465	10,959
01/04/05	0.042	194	4,578	1609	2,862	7,631	2,544	9,157
01/11/05	0.042	197	4,649	1624	2,906	7,749	2,735	7,749
01/18/05	0.045	10	224	56	152	318	147	381
01/25/05	0.023	16	704	176	487	1,056	453	1,152
02/01/05	0.029	12	416	84	309	601	293	637
02/08/05	0.060	6	100	15	79	125	76	132
02/15/05	0.078	9	116	14	96	139	92	144
02/22/05	0.083	5	60	7	50	72	48	76
03/08/05	0.076	1	13	1.5	11	16	10	17
03/15/05	0.069	1	15	3.0	10.3	19.9	10.0	21.3
03/22/05	0.037	3	80	21	53	116	51	128
03/29/05	0.042	3	71	26	45	119	40	143
04/05/05	0.071	1	14	2.7	10.3	18.5	10.0	20.6
04/26/05	0.029	2	70	32	40	112	37	140
05/03/05	0.029	10	349	132	199	558	186	698
05/10/05	0.029	4	140	54	80	223	74	279
05/17/05	0.065[d]	2	31	5	24	40	23	43
05/24/05	0.065[d]	2	31	5	24	40	23	43
05/31/05	0.065[d]	1	15	2.5	12	20	11	21
08/02/05	0.065[d]	1	15	2.5	12	20	11	21
Totals	**---**	***962***	***26,763***	***3,091***	***22,614***	***32,162***	***22,131***	***33,695***

[a] Half-cone season average efficiency was calculated using all valid un-pooled and pooled trials conducted January 4 to May 13, 2005. The half-cone season average was applied during weeks when no mark-recapture trials were conducted, and the trap was operating at half-cone.

[b] Daily catch was estimated for days the trap was not fishing.

[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.

[d] Full-cone season average efficiency was calculated using all valid un-pooled and pooled trials conducted January 4 to May 13, 2005. The full-cone season average was applied during weeks when no mark-recapture trials were conducted, and the trap was operating at full-cone.

Table 10. Weekly summary of brood year 2005 juvenile late-fall Chinook salmon passage estimates for the Upper Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Shaded rows indicate adjacent weeks where the results of mark-recapture trials were pooled to calculate passage. Only weeks in which late-fall Chinook salmon were captured are included. A 3-month period outside of the reporting dates (October 1 to December 31, 2005) was included to allow estimation of the total annual JPI for brood year 2005 (below dashed line).

Week	Efficiency (E)	Catch[a]	Estimated Passage (N)	SE[b]	90% Confidence Interval[b]		95% Confidence Interval[b]	
					Lower CI	Upper CI	Lower CI	Upper CI
04/05/05	0.071	4	56	12	41	78	39	83
04/12/05	0.047	1	21	4	16	29	15	33
05/10/05	0.029	2	70	30	40	112	37	140
10/1 to 12/31/05[c]	---	0	---	---	---	---	---	---
Totals	**---**	***7***	***147***	***32***	***112***	***198***	***109***	***213***

[a] Daily catch was estimated for days the trap was not fishing.
[b] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.
[c] No additional late-fall Chinook salmon were captured during this period.

Table 11. Weekly summary of rainbow trout/steelhead passage estimates for the Upper Battle Creek rotary screw trap, including week, efficiency (E), catch, estimated passage (N), standard error (SE), and the 90 and 95% confidence intervals (CI). Weekly estimates listed above the dotted line are for trout from previous brood years (age 1+). Weekly estimates below the line are for brood year 2005 trout captured during the reporting period. Shaded rows indicate adjacent weeks where the results of mark-recapture trials were pooled to calculate passage. Weeks with no catch are not included.

Week	Efficiency (E)	Catch[b]	Estimated Passage (N)	SE[c]	90% Confidence Interval[c]		95% Confidence Interval[c]	
					Lower CI	Upper CI	Lower CI	Upper CI
Previous Brood Years (Age 1+)								
10/19/04	0.032[a]	1	31	8	21	46	20	50
12/28/04	0.032[a]	1	31	8	21	46	20	50
02/01/05	0.029	1	35	7	26	47	24	50
02/08/05	0.060	1	17	2	14	21	13	22
02/15/05	0.078	4	51	6	42	62	41	63
02/22/05	0.083	4	48	6	40	58	39	61
03/01/05	0.044	3	69	12	53	93	51	97
03/29/05	0.042	1	24	9	14	40	13	48
04/05/05	0.071	4	56	11	41	74	38	83
05/10/05	0.029	3	105	53	60	167	56	209
05/24/05	0.065[d]	1	15	3	12	20	11	21
Totals	---	***24***	***482***	***59***	***419***	***570***	***407***	***612***
Brood Year 2005 (YOY)								
02/01/05	0.029	1	35	7	26	47	24	50
02/22/05	0.083	1	12	1.4	9.9	14.2	9.5	15.0
03/01/05	0.044	1	23	4	18	30	17	32
03/08/05	0.076	5	66	8	54	79	53	83
03/15/05	0.069	5	73	16	53	100	50	106
03/22/05	0.037	4	107	28	71	155	68	171
03/29/05	0.042	13	309	136	193	516	182	619
04/05/05	0.071	16	225	47	165	312	156	330
04/12/05	0.047	13	278	52	206	380	195	401
04/19/05	0.089	3	34	12	19	54	18	68
04/26/05	0.029	8	279	113	159	446	149	558
05/03/05	0.029	41	1,430	541	817	2,288	763	2,860
05/10/05	0.029	53	1,848	666	1,056	2,957	986	3,697
05/17/05	0.065[d]	11	168	29	129	225	124	243

Table 11 (Cont.)

05/24/05	0.065[d]	11	168	28	127	217	122	234
05/31/05	0.065[d]	7	107	17	82	138	79	143
06/07/05	0.065[d]	10	153	26	118	198	123	213
06/14/05	0.065[d]	3	46	8	35	59	34	64
06/21/05	0.065[d]	1	15	3	12	20	11	21
06/28/05	0.065[d]	1	15	3	12	20	11	21
07/05/05	0.065[d]	3	46	8	35	59	34	64
09/21/05	0.065[d]	1	15	8	12	20	11	21
Totals	---	***212***	***5,452***	***890***	***4,341***	***7,071***	***4,166***	***7,519***

[a] Half-cone season average efficiency was calculated using all valid un-pooled and pooled trials conducted January 4 to May 13, 2005. The half-cone season average was applied during weeks when no mark-recapture trials were conducted, and the trap was operating at half-cone.
[b] Daily catch was estimated for days the trap was not fishing.
[c] Confidence intervals were calculated using the percentile bootstrap method and SE's were calculated using bootstrapped values.
[d] Full-cone season average efficiency was calculated using all valid un-pooled and pooled trials conducted January 4 to May 13, 2005. The full-cone season average was applied during weeks when no mark-recapture trials were conducted, and the trap was operating at full-cone.

Table 12. Summary of spring, fall, and late-fall Chinook salmon and rainbow trout/steelhead juvenile passage estimates at the Lower Battle Creek rotary screw trap including run designation, brood year, original CAMP estimate, current estimate (N), and the 90 and/or 95% confidence intervals for the current estimates. Shaded rows indicated estimates for the current reporting period.

Run	Brood Year	Original CAMP Estimate[c]	Current Estimate	90% Confidence Interval		95% Confidence Interval	
				Lower CI	Upper CI	Lower CI	Upper CI
Spring	1998	---	---	---	---	---	---
	1999	---	---	---	---	---	---
	2000	---	---	---	---	---	---
	2001	---	8,978	8,113	10,002	8,003	10,160
	2002	---	2,315	2,078	2,628	2,037	2,713
	2003	---	14,809	13,139	16,632	12,809	16,922
	2004	---	7,983	6,434	10,015	6,256	10,884
Fall	1998	4,909,700	4,897,569	---	---	4,238,511	5,732,692
	1999	16,697,610	18,708,768	---	---	14,103,348	26,372,818
	2000-partial[a]	---	5,451,599	---	---	4,270,908	7,182,598
	2001	---	4,040,686	3,721,942	4,413,372	3,676,854	4,522,353
	2002	---	581,677	542,513	625,834	537,926	636,193
	2003	---	3,143,957	2,863,640	3,492,043	2,821,952	3,598,515
	2004	---	4,349,127	3,822,231	4,993,838	3,724,470	5,174,112
Late-Fall	1999	113,684	86,305	---	---	72,258	98,591
	2000	99,803	86,940	---	---	73,793	106,967
	2001	---	---	---	---	---	---
	2002	---	59,183	50,087	72,672	48,738	75,194
	2003	---	31,538	29,371	34,371	29,126	34,580
	2004	---	23,193	20,497	26,193	20,103	26,875
	2005	---	66,751	54,101	85,553	52,189	90,209
RBT/Steelhead	1999[b]	---	7,057	---	---	6,196	8,368
	2000[b]	---	8,417	---	---	7,699	9,608
	2001	---	---	---	---	---	---
	2002 (1+)[d]	---	647	583	725	574	735
	2002 (YOY)	---	8,153	7,261	9,255	7,096	9,576
	2003 (1+)[d]	---	577	540	622	633	632
	2003 (YOY)	---	2,313	2,164	2,479	2,187	2,520

Table 12 (Cont.)

2004 (1+)[d]	---	471	421	526	413	538
2004 (YOY)	---	1,144	1,031	1,268	1,013	1,301
2005 (1+)[d]		357	291	447	284	469
2005 (YOY)		3,422	2,809	4,289	2,739	4,682

[a] This passage estimate is not a complete brood year as the trap was not fished past February 9, 2001.

[b] These estimates are not brood years, rather two periods are summarized: October 9, 1998 to December 26, 1999 and December 27, 1999 to February 9, 2001.

[c] The original CAMP estimates cover the period January 1 through December 31; therefore, they may not include the entire brood year, and late-fall estimates may include fish from two brood years.

[d] Passage estimates for age 1+ trout are not for the current brood year, but rather a mixture of previous year-classes captured during the reporting period.

Table 13. Summary of spring, fall, and late-fall Chinook salmon and rainbow trout/steelhead juvenile passage estimates at the Upper Battle Creek rotary screw traps including run designation, brood year, original CAMP estimate, current estimate (N), and the 90 and/or 95% confidence intervals for the current annual estimates. Shaded rows indicated estimates for the current reporting period.

Run	Brood Year	Original CAMP Estimate[c]	Current Estimate	90% Confidence Interval Lower CI	90% Confidence Interval Upper CI	95% Confidence Interval Lower CI	95% Confidence Interval Upper CI
Spring	1998	4,589	4,791	---	---	3,949	6,204
	1999	10,061	6,233	---	---	5,225	7,678
	2000	---	---	---	---	---	---
	2001	---	482	389	615	377	644
	2002	---	926	810	1,070	798	1,102
	2003	---	11,264	9,251	14,026	8,973	14,709
	2004	---	3,253	2,803	3,835	2,748	3,996
Fall	1998	1,466,274	1,193,916	---	---	996,588	1,546,430
	1999	211,662	239,152	---	---	202,274	291,194
	2000-partial[a]	---	43,850	---	---	37,476	54,567
	2001	---	20,920	18,642	24,337	18,195	25,143
	2002	---	17,754	15,883	19,731	15,648	20,244
	2003	---	141,393	128,557	155,900	127,193	160,251
	2004	---	26,763	22,614	32,162	22,131	33,695
Late-Fall	1999	---	212	177	261	170	273
	2000	---	50	36	70	35	78
	2001	---	---	---	---	---	---
	2002	---	7,628	5,950	9,969	5,753	10,604
	2003	---	6,673	5,835	7,409	5,679	7,631
	2004	---	1,145	809	1,732	768	1,968
	2005	---	147	112	198	109	213
RBT/Steelhead	1999[b]	---	10,388	---	---	8,810	12,976
	2000[b]	---	25,710	---	---	21,865	30,713
	2001	---	---	---	---	---	---
	2002 (1+)[d]	---	1,348	1,201	1,607	1,170	1,666
	2002 (YOY)	---	24,740	21,034	29,565	20,454	31,426
	2003 (1+)[d]	---	592	522	671	511	698
	2003 (YOY)	---	7,087	6,441	7,769	6,349	7,978

Table 13 (Cont.)

	2004 (1+)[d]	---	826	753	903	741	917
	2004 (YOY)	---	2,770	2,512	3,057	2,455	3,142
	2005 (1+)[d]	---	485	421	573	411	610
	2005 (YOY)	---	5,490	4,3	7,074	4,231	7,431

[a] This passage estimate is not a complete brood year as the trap was not fished past February 9, 2001.

[b] These estimates are not brood years, rather two periods are summarized: October 9, 1998 to December 26, 1999 and December 27, 1999 to February 9, 2001.

[c] The original CAMP estimates cover the period January 1 through December 31; therefore, they may not include the entire brood year, and late-fall estimates may include fish from two brood years.

[d] Passage estimates for age 1+ fish are not for the current brood year, but rather a mixture of previous year-classes captured during the reporting period.

Figures

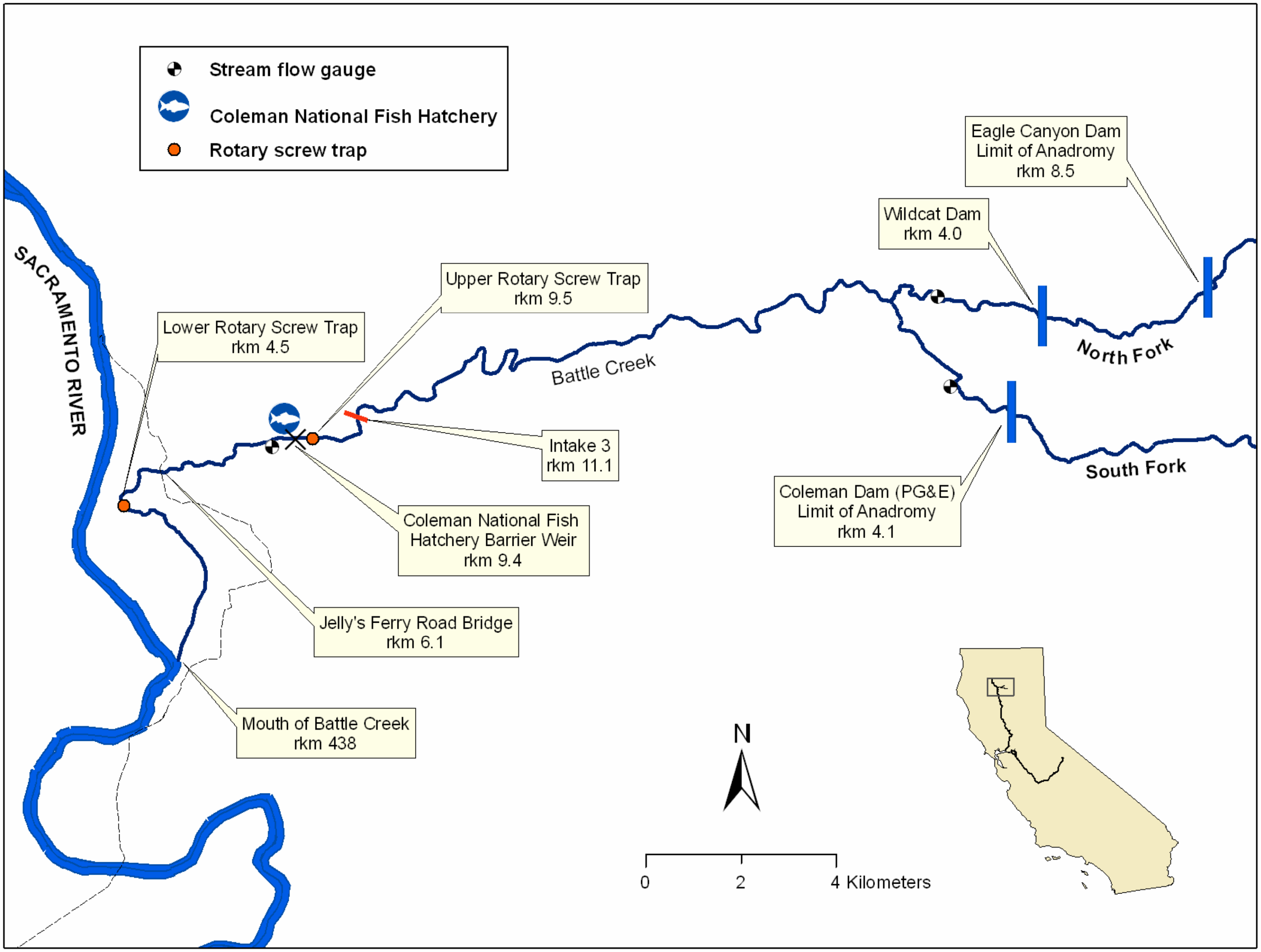

Figure 1. Map of Battle Creek depicting the location of USFWS' rotary screw traps and other important features.

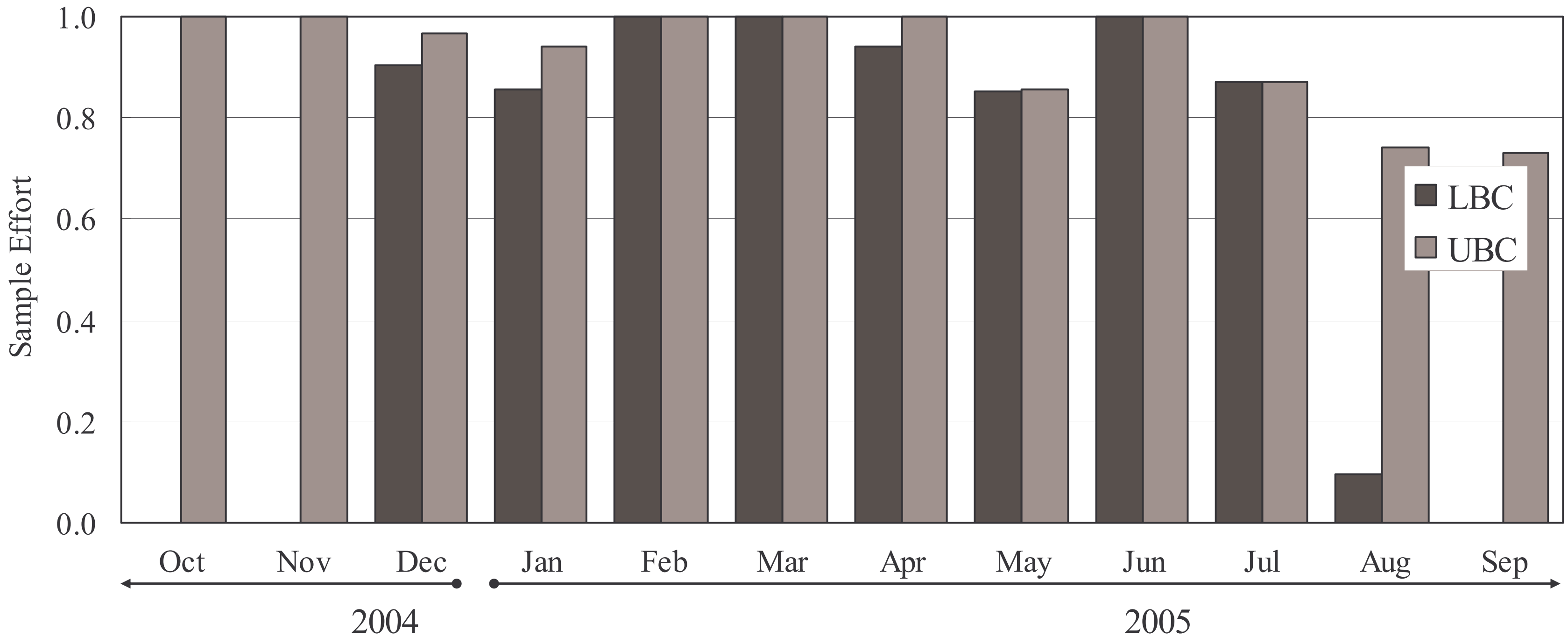

Figure 2. Sampling effort summarized as the proportion (range: 0 to 1) of days fished each month at the Lower and Upper Battle Creek rotary screw traps from October 1, 2004 to September 30, 2005. The LBC trap was not operated in October and November 2004, and neither trap was operated during all or most of August and September 2005.

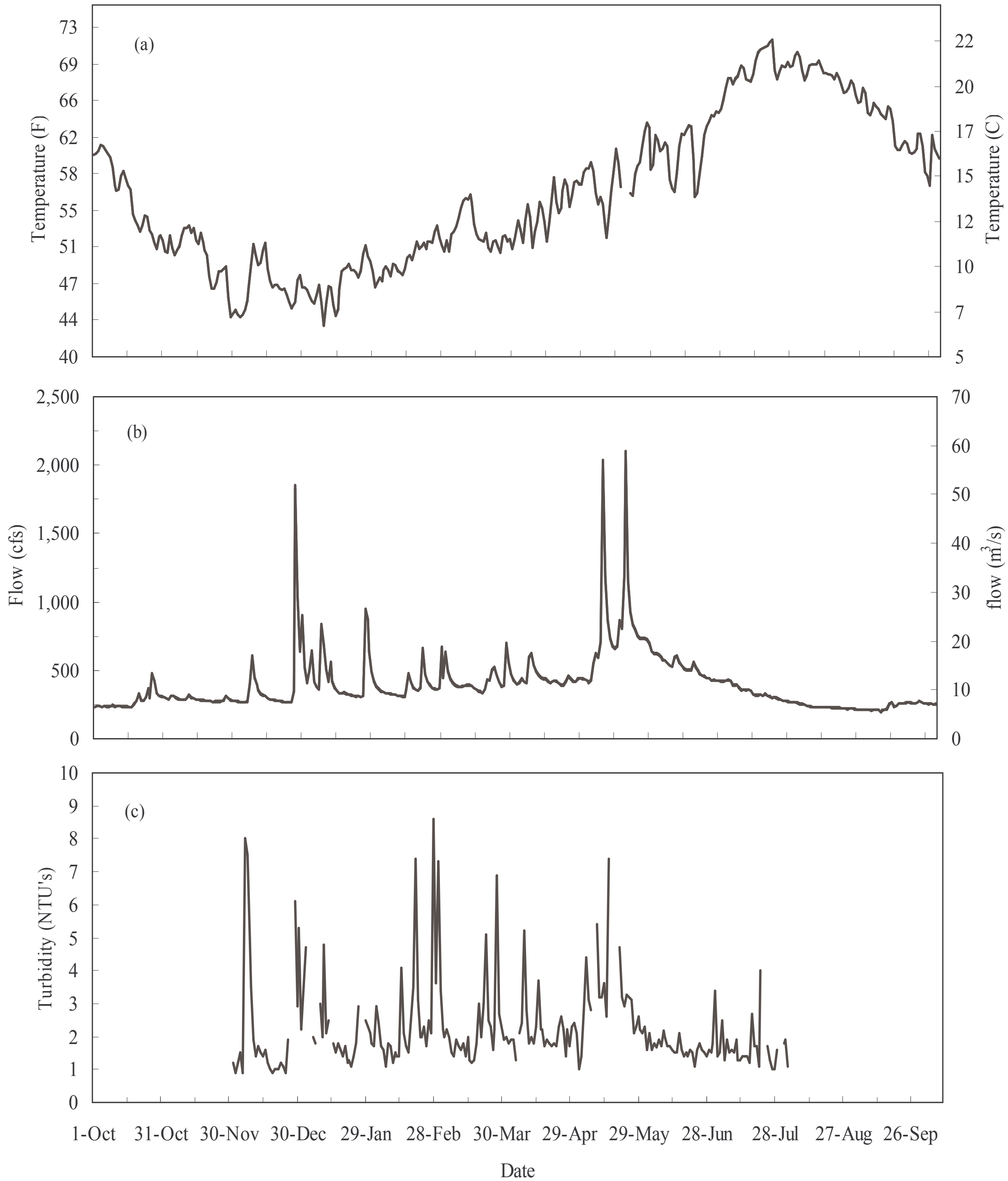

Figure 3. Mean daily temperature (a; ºC and ºF), mean daily flows (b; m^3/s and cfs), and turbidity (c; NTU's) at the Lower Battle Creek rotary screw trap from October 1, 2004 through September 30, 2005.

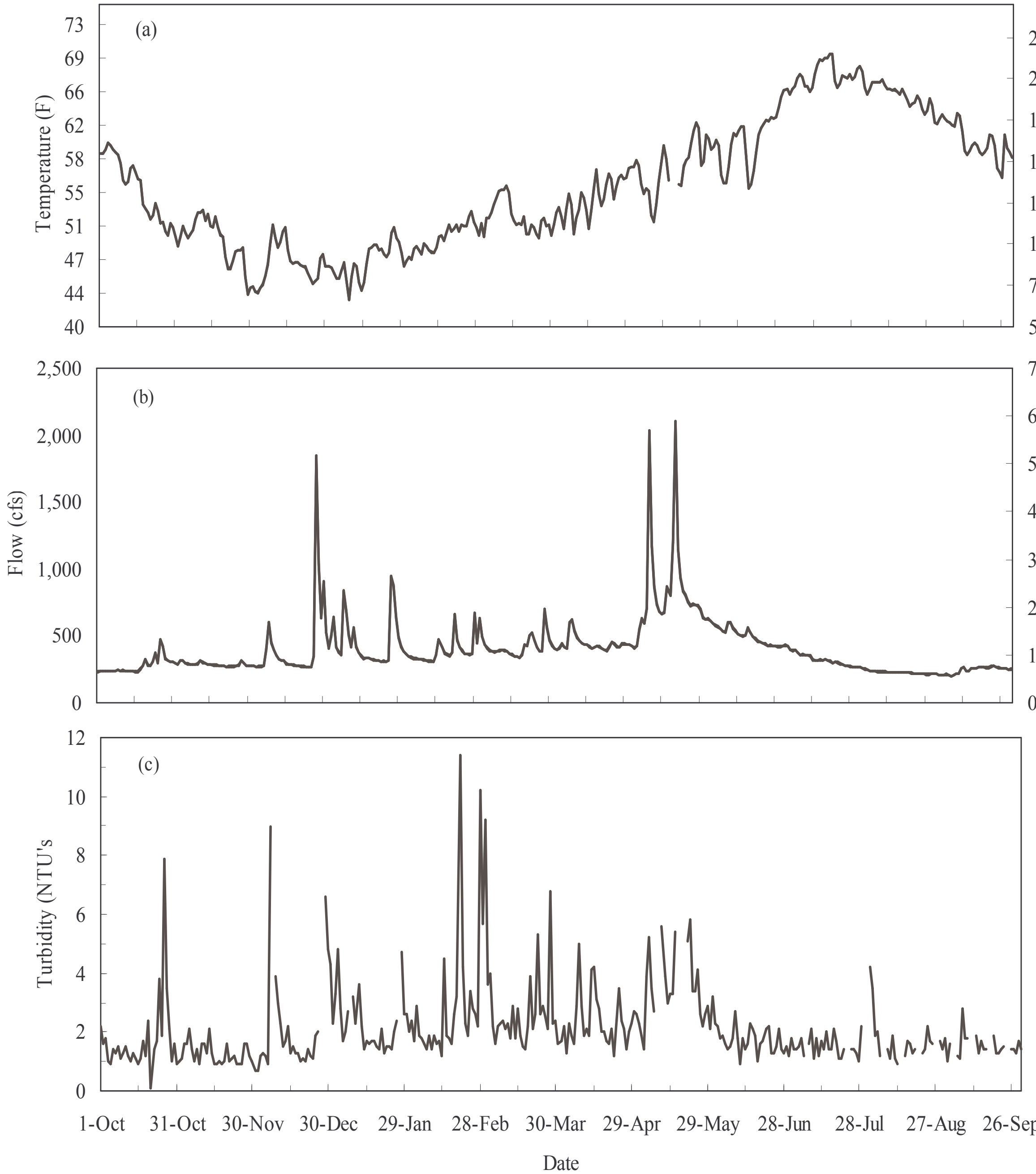

Figure 4. Mean daily temperature (a; ºF and ºC), mean daily flows (b; cfs and m^3/s), and turbidity (c; NTU's) at the Upper Battle Creek rotary screw trap from October 1, 2004 to September 30, 2005.

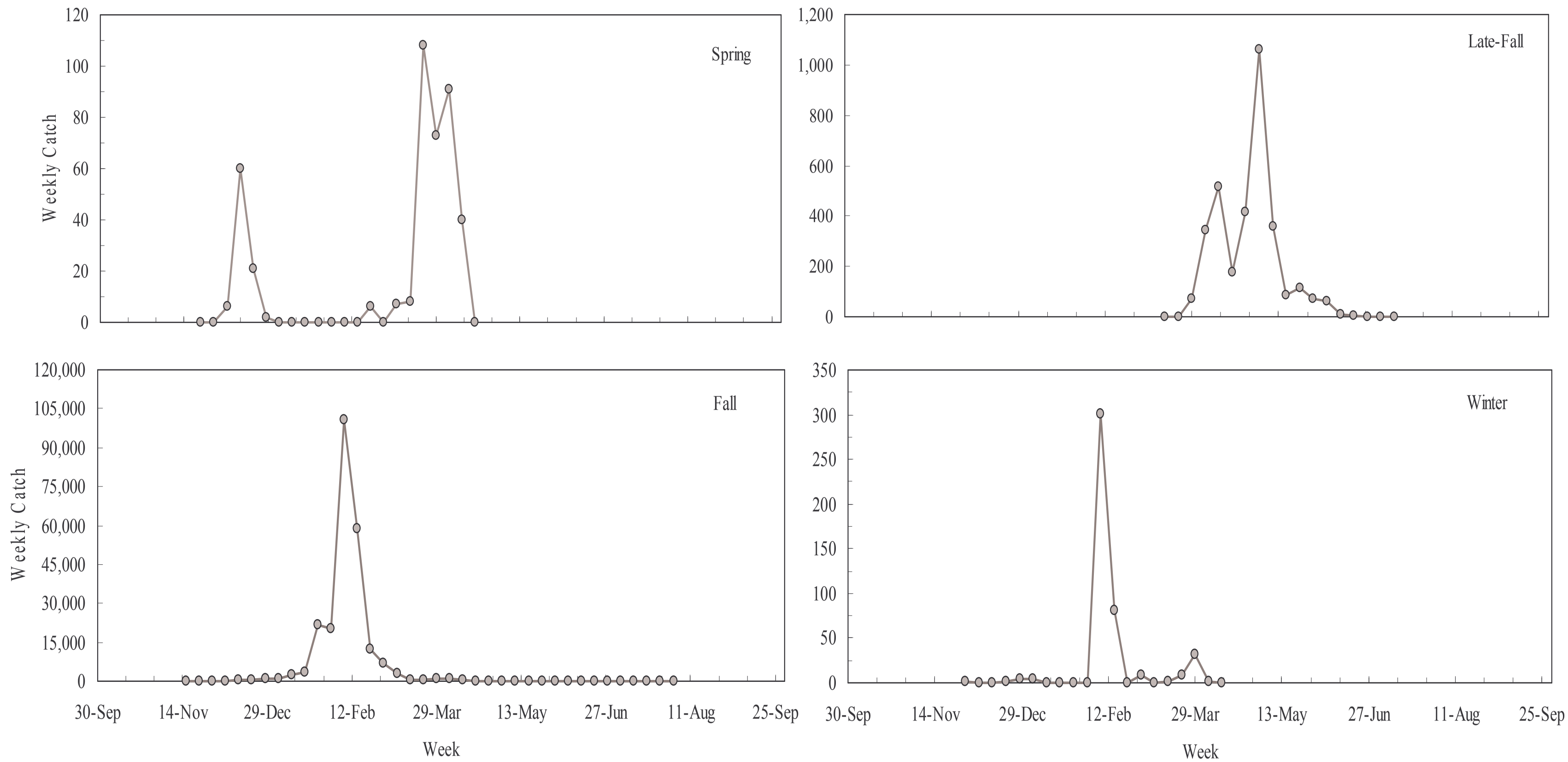

Figure 5. Weekly catch of spring, fall, late-fall, and winter Chinook salmon captured at the Lower Battle Creek rotary screw trap from October 1, 2004 to September 30, 2005. Run designation was assigned using the length-at-date criteria developed for the Sacramento River (Greene 1992).

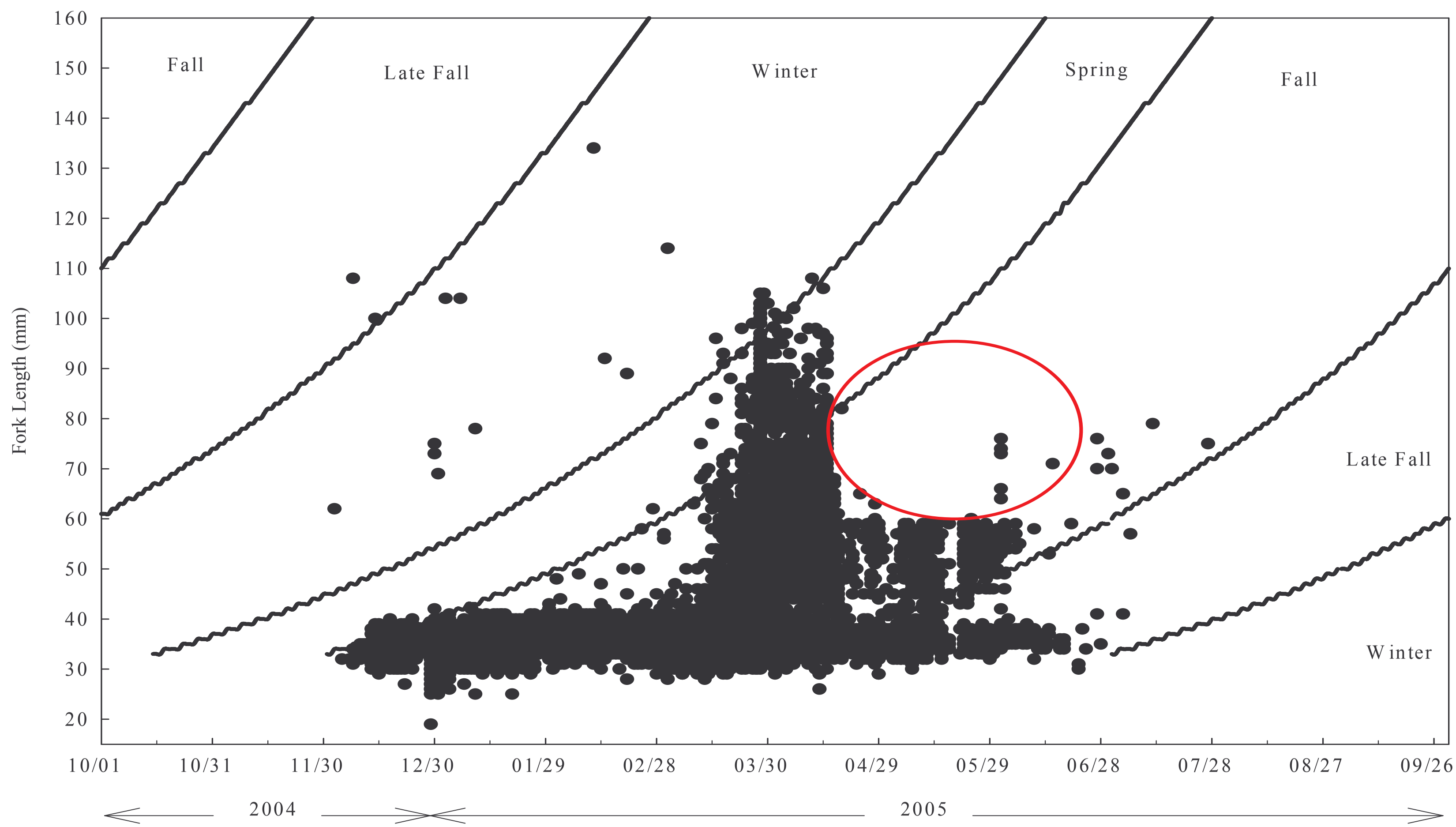

Figure 6. Fork length (mm) distribution by date and run for Chinook salmon captured at the Lower Battle Creek rotary screw trap from October 1, 2004 to September 30, 2005. Spline curves represent the maximum fork lengths expected for each run by date, based upon criteria developed by the California Department of Water Resources (Greene 1992). The red circle indicates the period when unmarked hatchery fall Chinook salmon were released. Most Chinook salmon ≥59 mm were not included as they were primarily hatchery fish.

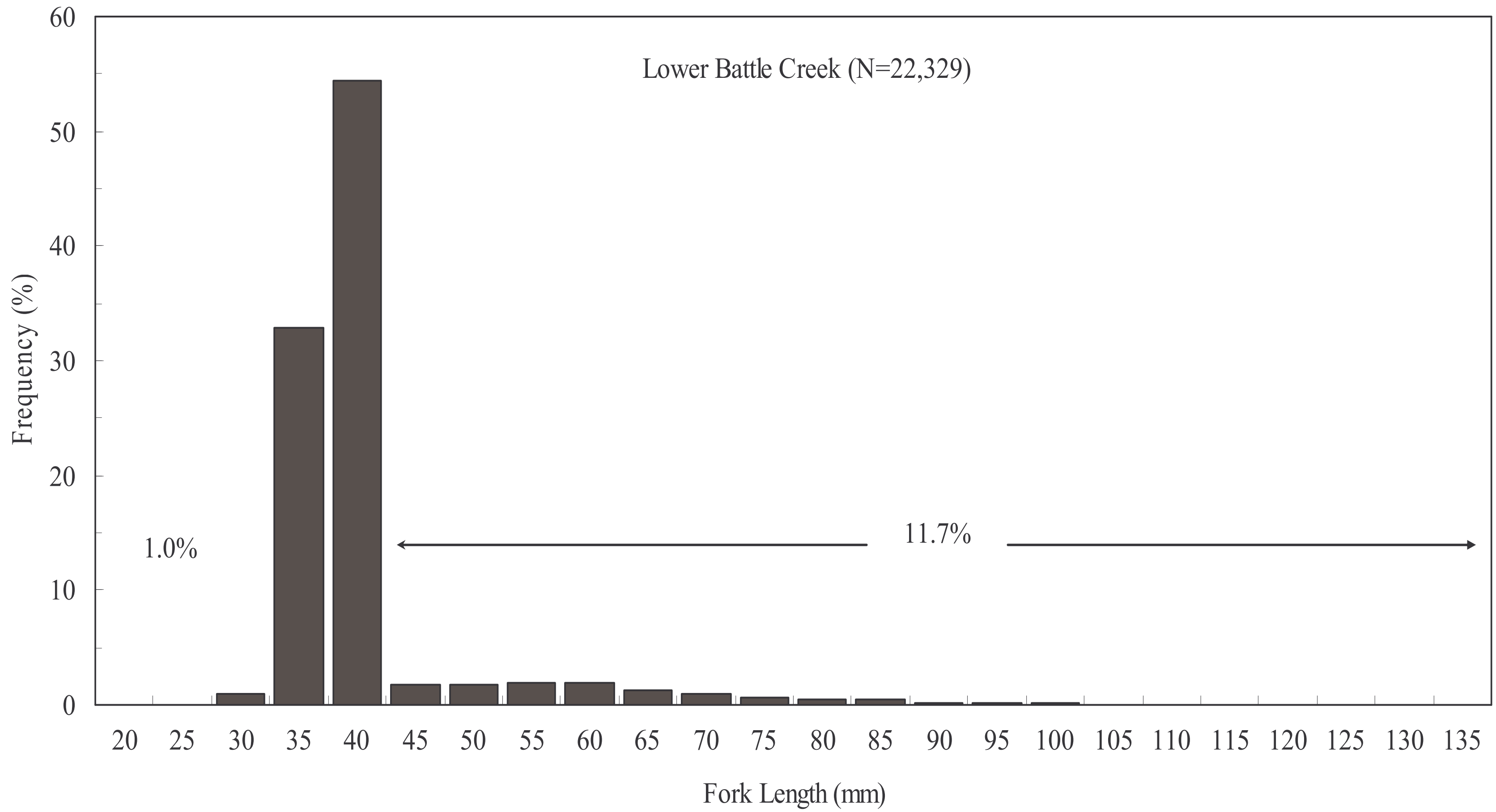

Figure 7. Length frequency (%) for all runs of Chinook salmon measured at the Lower Battle Creek rotary screw trap (LBC) from October 1, 2004 to September 30, 2005. Fork length axis labels indicate the upper limit of a 5-mm length range.

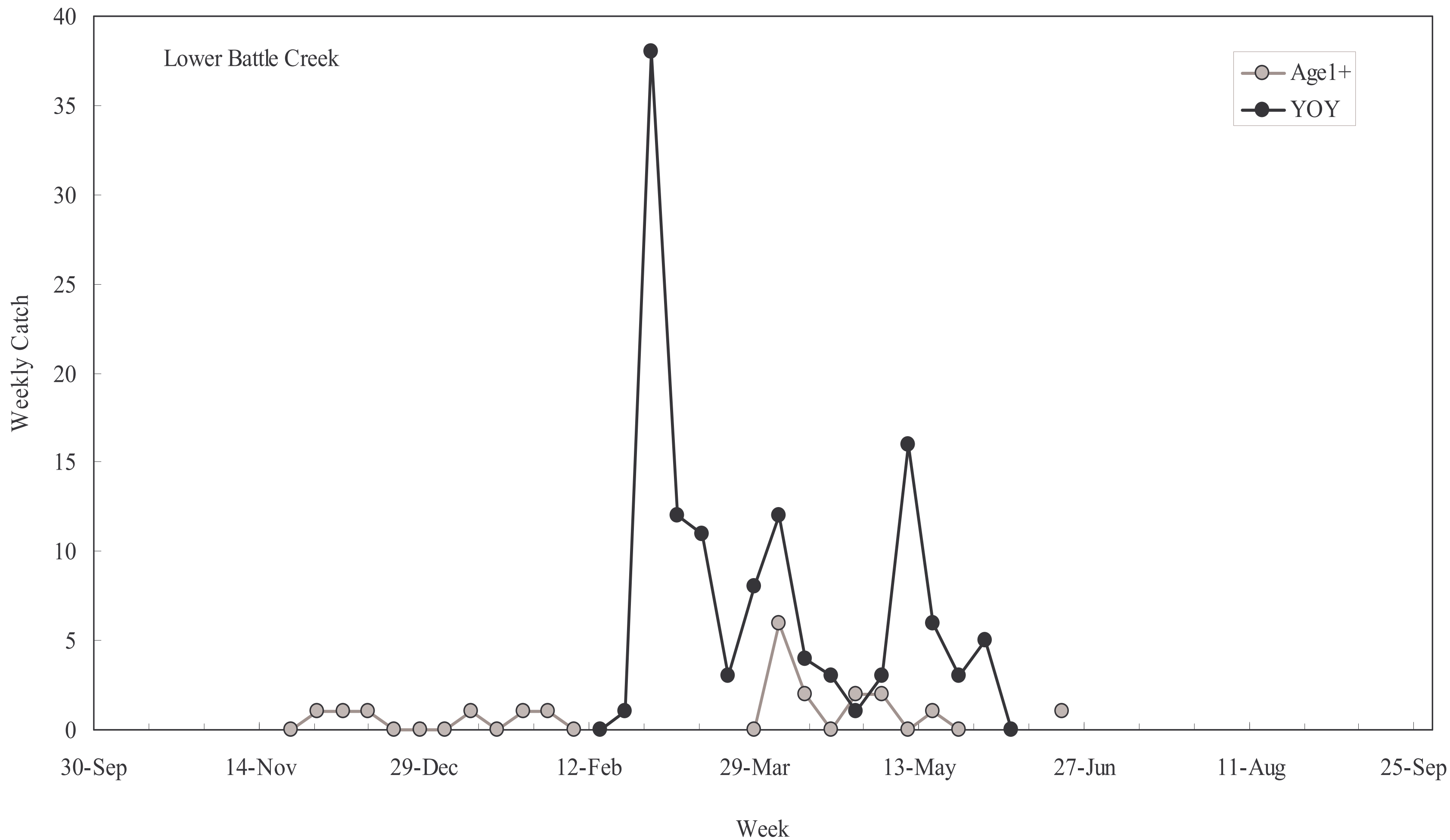

Figure 8. Weekly catch of rainbow trout/steelhead at the Lower Battle Creek rotary screw trap from October 1, 2004 to September 30, 2005.

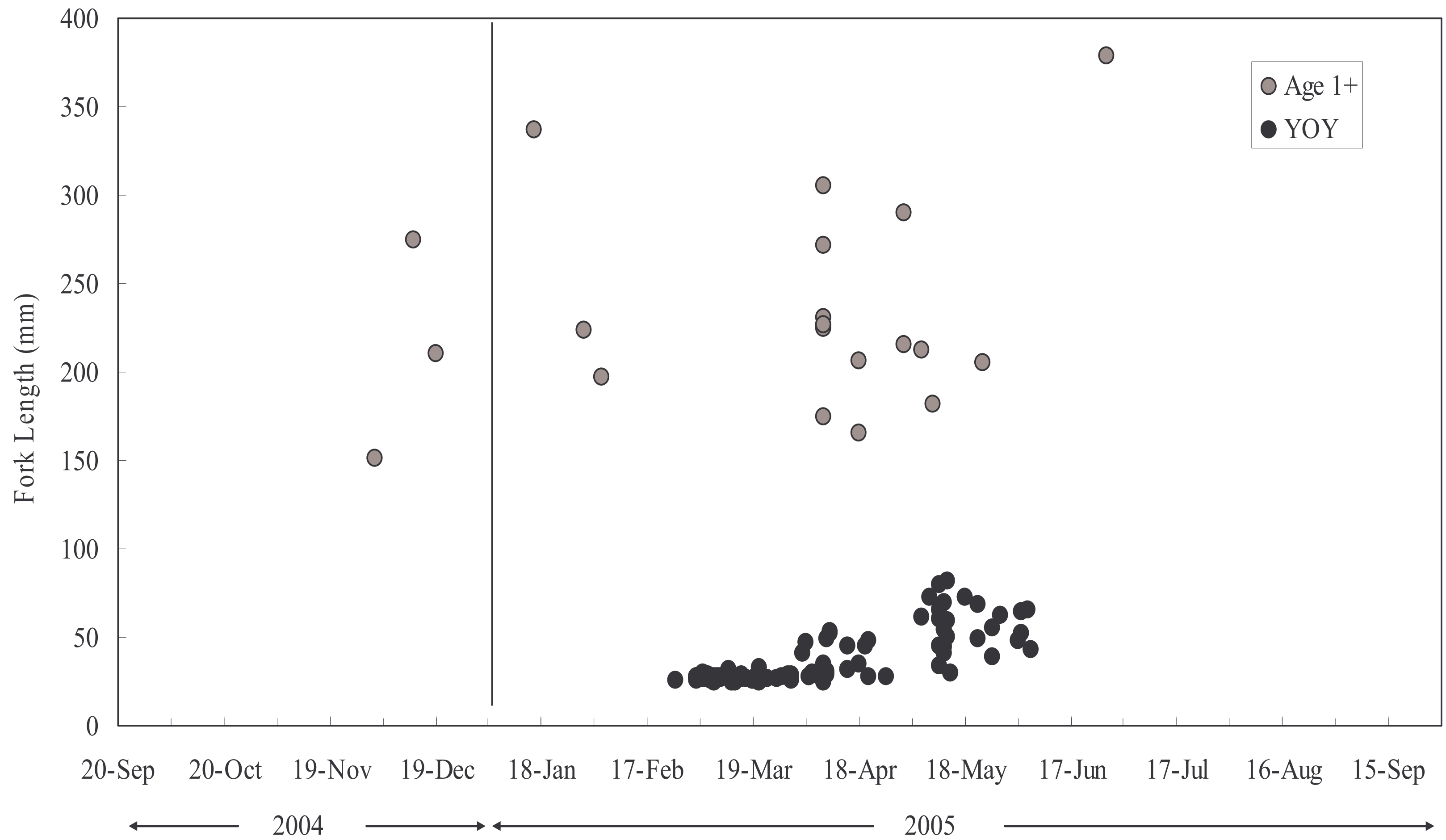

Figure 9. Fork length (mm) distribution for age 1+ and young-of-the-year (YOY) rainbow trout/steelhead sampled at the Lower Battle Creek rotary screw trap during October 1, 2004 through September 30, 2005. Age 1+ fish may include individuals from more than one year class.

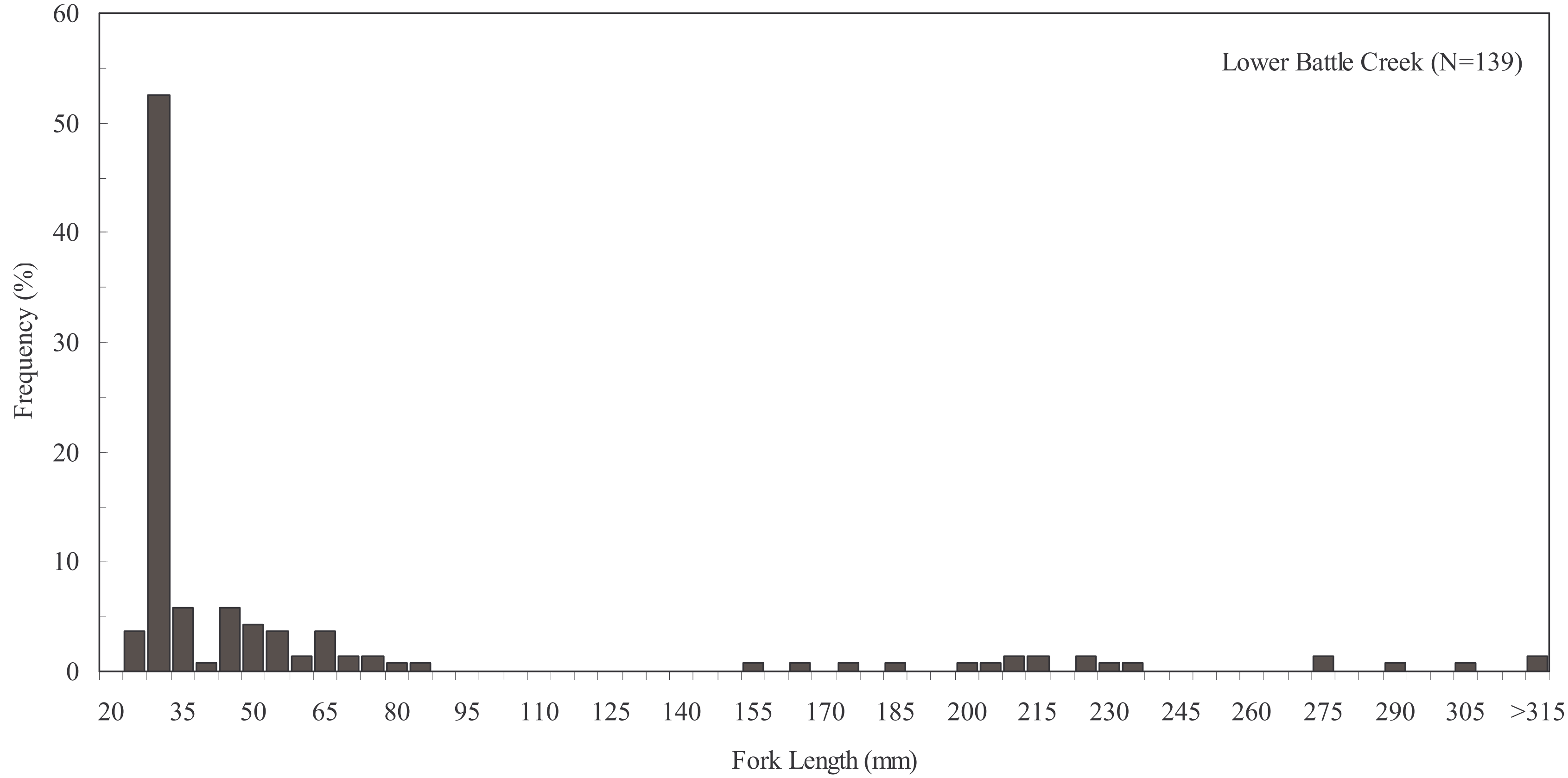

Figure 10. Fork length frequency (%) for rainbow trout/steelhead sampled at the Lower Battle Creek rotary screw trap during October 1, 2004 through September 30, 2005. Fork axis labels indicate the upper limit of a 5-mm length range.

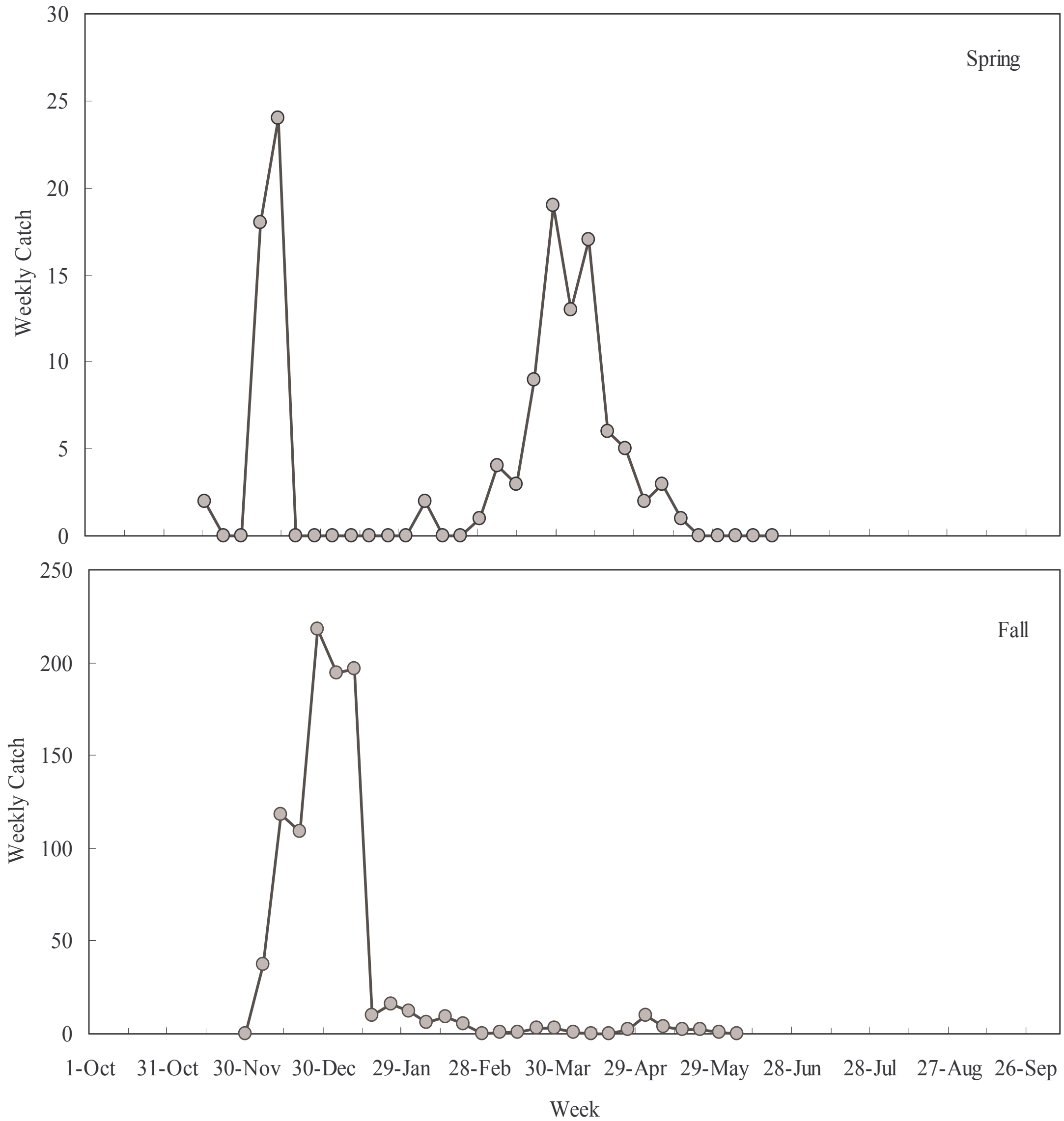

Figure 11. Weekly catch of spring and fall Chinook salmon captured at the Upper Battle Creek rotary screw trap from October 1, 2004 to September 30, 2005. Only seven late-fall and four winter Chinook salmon were captured; therefore they were not displayed graphically. Run designation was assigned using the length-at-date criteria developed for the Sacramento River (Greene 1992).

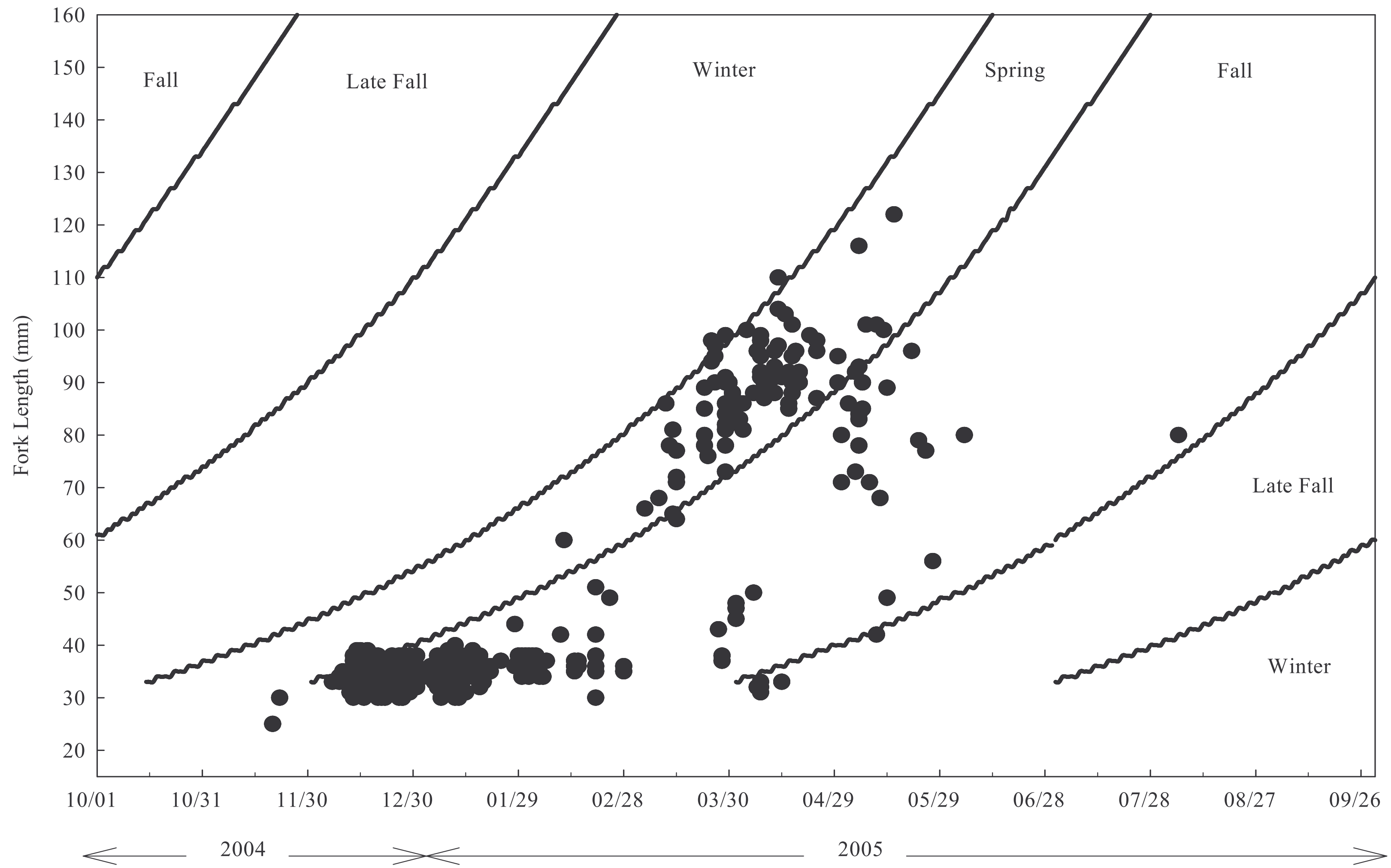

Figure 12. Fork length (mm) distribution by date and run for Chinook salmon captured at the Upper Battle Creek rotary screw trap from October 1, 2004 to September 30, 2005. Spline curves represent the maximum fork lengths expected for each run by date, based on criteria developed by the California Department of Water Resources (Greene 1992).

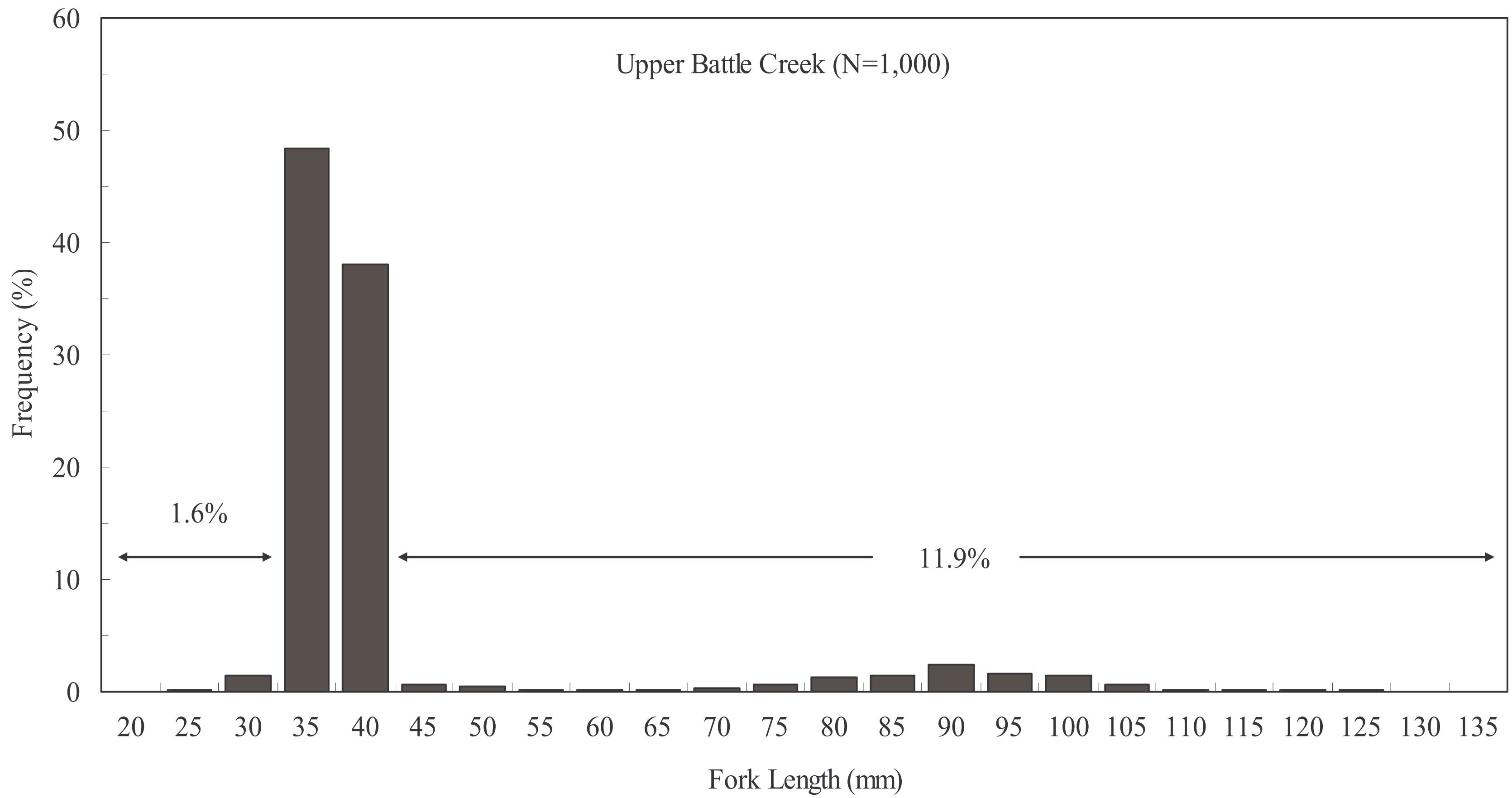

Figure 13. Length frequency (%) for all runs of Chinook salmon measured at the Upper Battle Creek rotary screw trap (UBC) during October 1, 2004 through September 30, 2005. Fork length axis labels indicate the upper limit of a 5-mm length range.

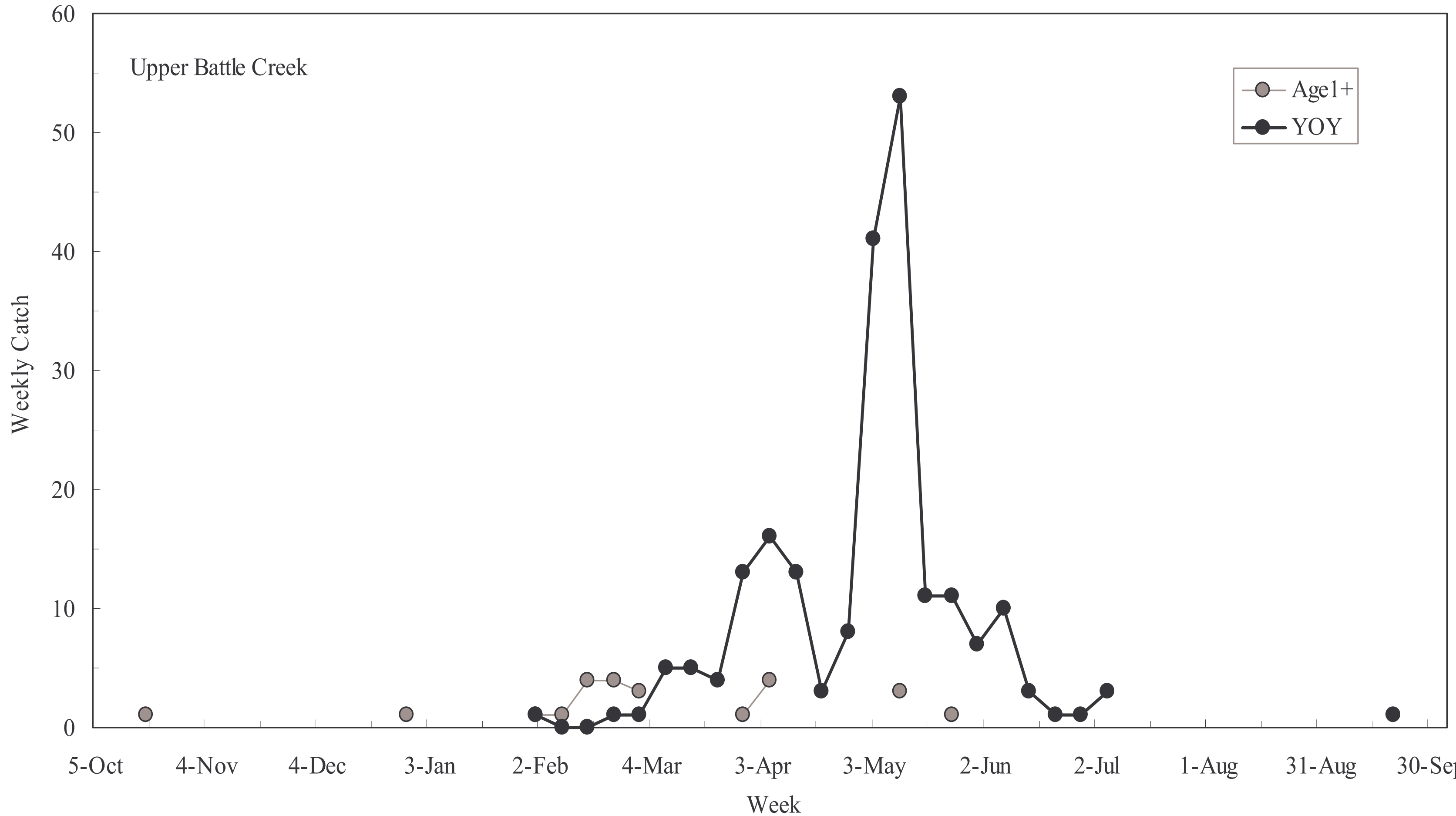

Figure 14. Weekly catch of rainbow trout/steelhead at the Upper Battle Creek rotary screw trap from October 1, 2004 to September 30, 2005.

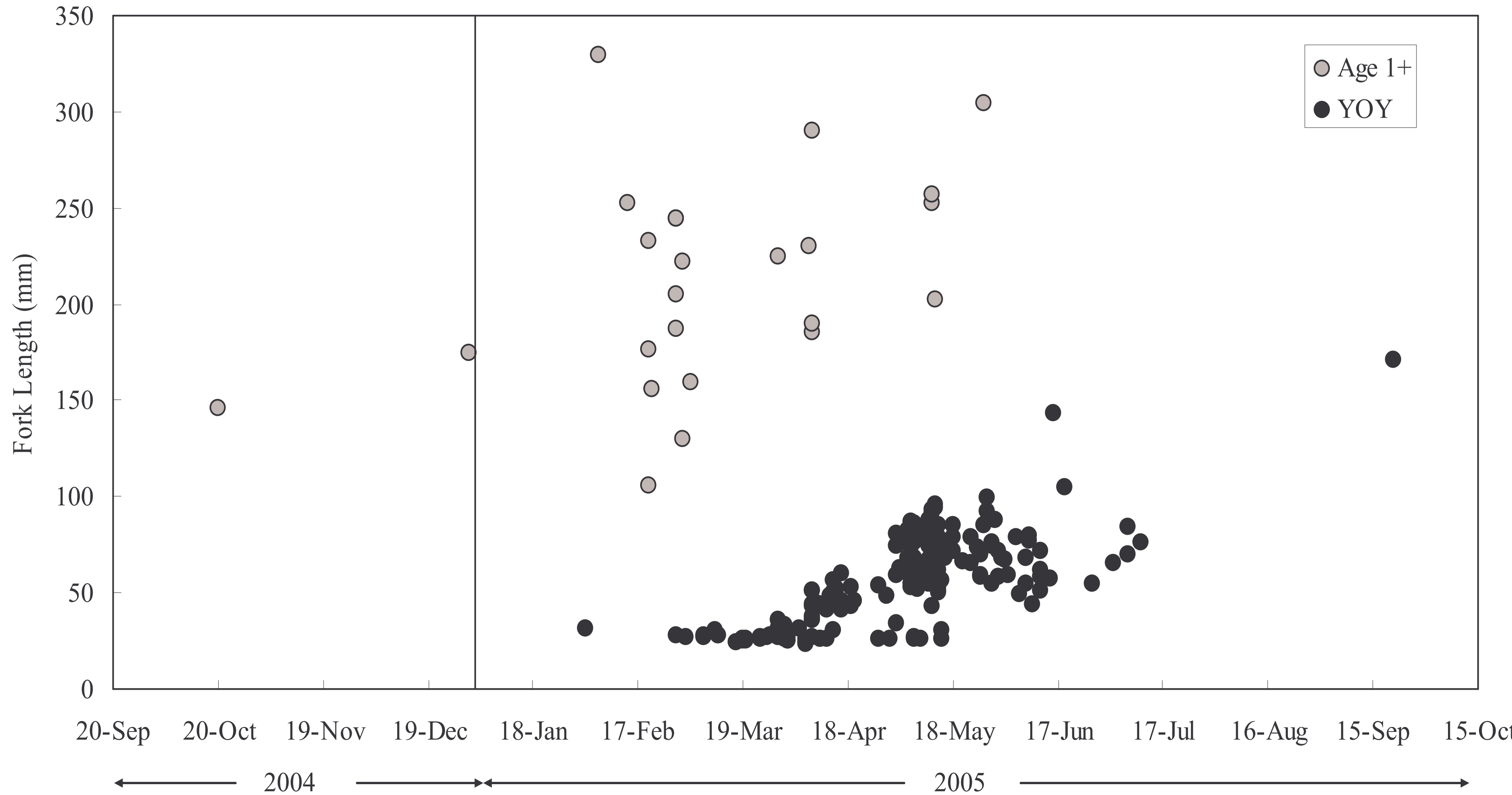

Figure 15. Fork length (mm) distribution by date for age 1+ and young-of-the-year rainbow trout/steelhead measured at the Upper Battle Creek rotary screw trap during October 1, 2004 through September 30, 2005. Age 1+ fish may include individuals from more than one year class.

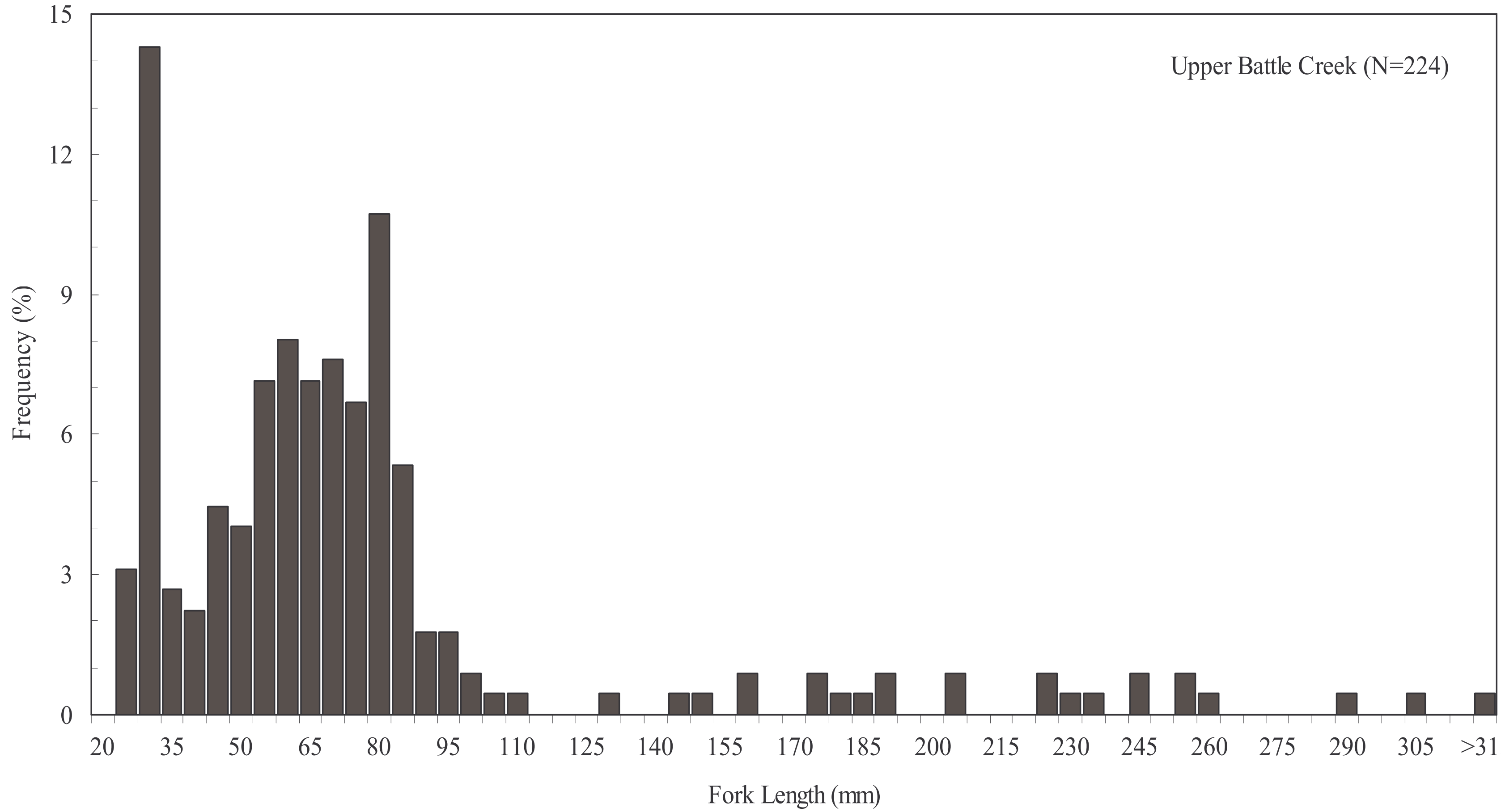

Figure 16. Fork length frequency (%) for rainbow trout/steelhead sampled at the Upper Battle Creek rotary screw trap during October1, 2004 through September 30, 2005. Fork axis labels indicate the upper limit of a 5-mm length range.

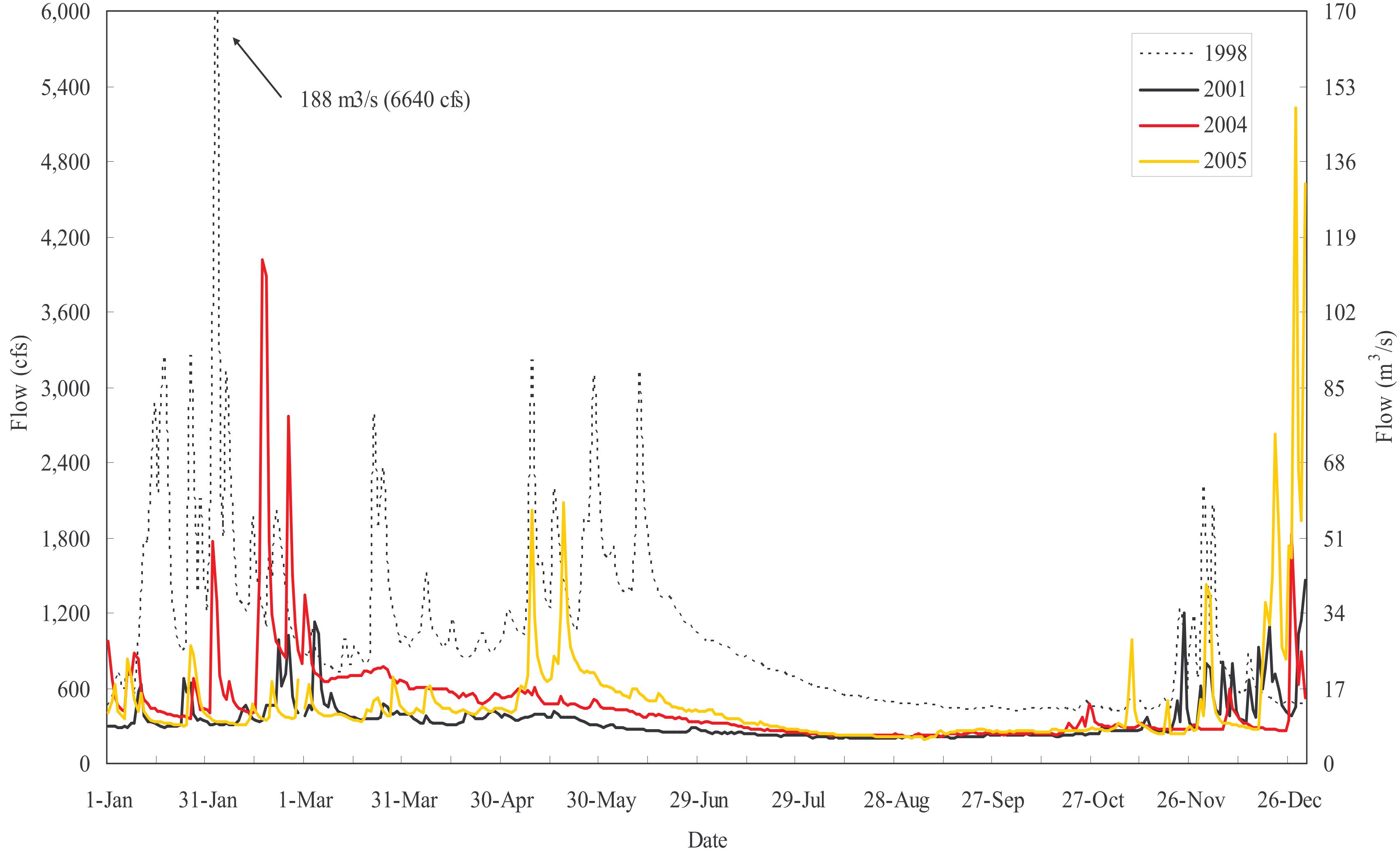

Figure 17. Mean daily flows (m^3/s) recorded at the U. S. Geological Survey gauging station (BAT-#11376550) located below the Coleman National Fish Hatchery barrier weir, January 1, 2004 to December 31, 2005. Flows for the wettest (1998) and driest (2001) years of sampling are included for comparison.

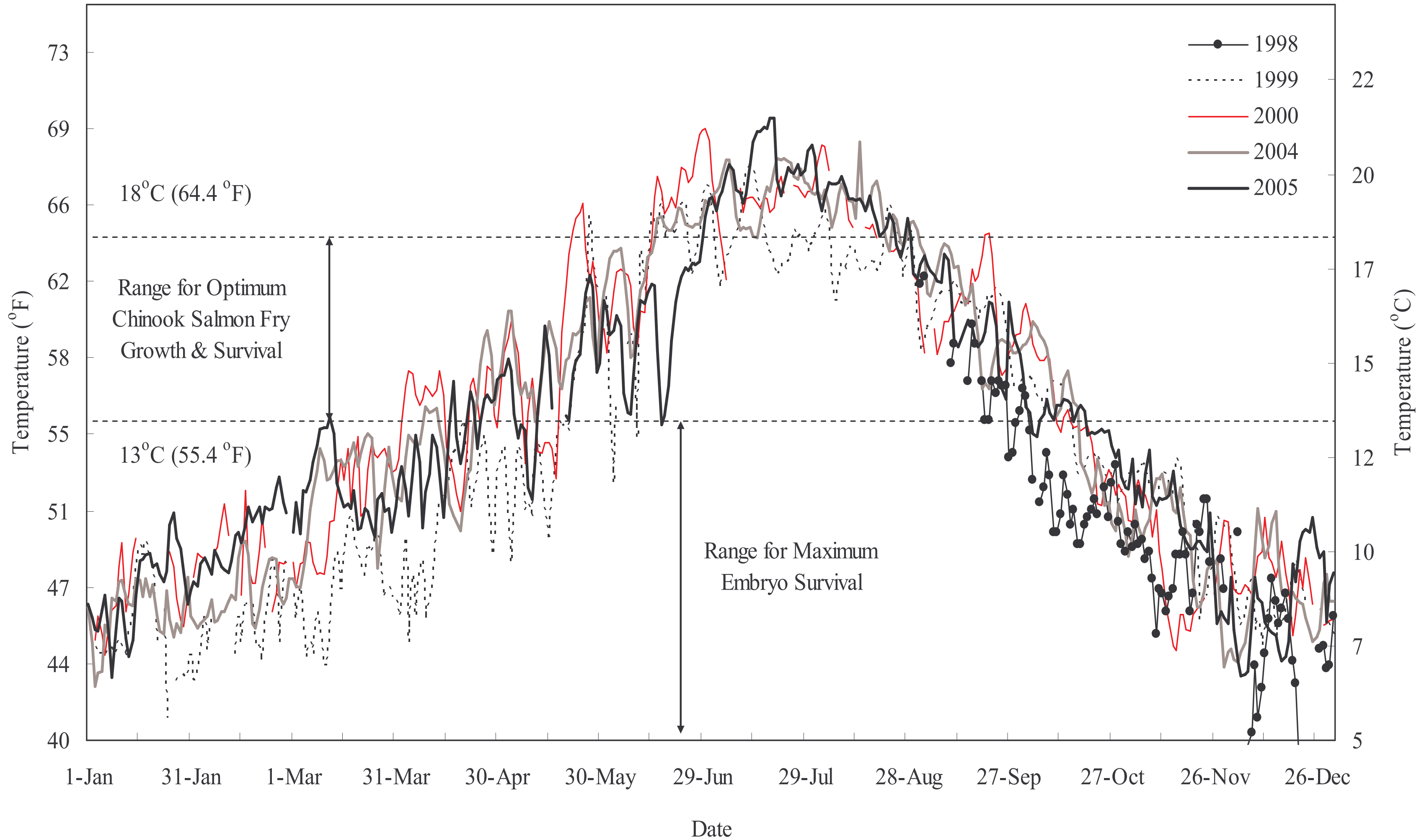

Figure 18. Mean daily water temperatures at the Upper Battle Creek rotary screw trap for 1998-2000 and 2004 through 2005. In 1998, data was not available prior to trap operation. Temperatures for 1998 to 2000 were included to allow comparisons between the current sample period (October 1, 2004 to September 30, 2005) and years when temperatures in general were the coolest and warmest during monitoring. Temperature ranges for optimum Chinook salmon embryo survival and fry growth and survival are included.

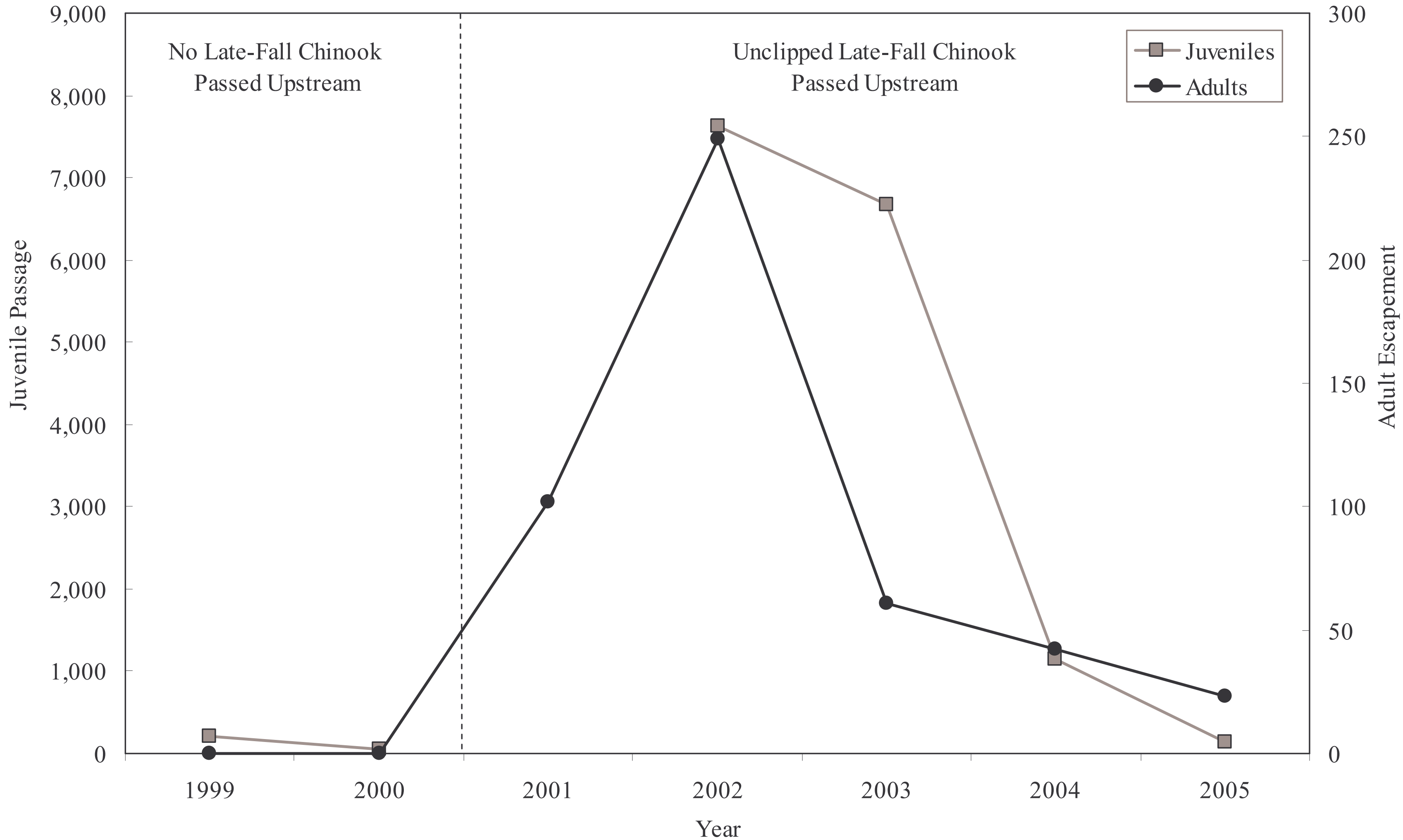

Figure 19. Relationship between late-fall Chinook salmon juvenile passage and adult escapement at the Upper Battle Creek trap (UBC) for brood years 1999-2000 and 2002-2005. A juvenile passage estimate could not be made in 2001 because the trap was not operated after February 2001.

Appendix

Appendix 1. Summary of days the Lower Battle Creek rotary screw trap did not fish during the report period (October 1, 2004 to September 30, 2005), including sample dates, hours fished, and reason for not fishing.

Sample Dates	Hours Fished (approx)	Reason
	2004	
October 1 to December 1	0	Trap out/ No Outmigration
December 27-28		High Flows
	2005	
January 4-5	0	Late-fall Hatchery Release
January 8	3	High Flows
January 14	0	Late-fall Hatchery Release
April 16	0	Fall Hatchery Release
May 9–10	11	High Flows
May 17 and 19-20	0	High Flows
July 23-24 and 30-31	0	Reduced Sampling – Limited Salmonid Catch
August 4 to September 30	0	Little or No Salmonid Catch

Appendix 2. Summary of days the Upper Battle Creek rotary screw trap did not fish during the report period (October 1, 2004 to September 30, 2005), including sample dates, hours fished, and reason for not fishing.

Sample Dates	Hours Fished	Reason
	2004	
December 28	0	High Flows
	2005	
January 8	0	High Flows
January 27	0	High Flows
May 9-10	11	High Flows
May 17 and 19-20	0	High Flows
July 23-24 and 30-31	0	Reduced Sampling – Limited Salmonid Catch
August 6-7, 13-14, 20-21 and 27-28	0	Reduced Sampling – Limited Salmonid Catch
September 3-4, 10-11, 17-18, and 24-25	0	Reduced Sampling – Limited Salmonid Catch